APPENDIX G

Sediment Conditions in the Lower Boise River

Sediment Problem Assessment for the Lower Boise River TMDL

PREPARED FOR: Lower Boise River Water Quality Plan

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Regulatory Background

From the Diversion Dam to the Snake River, the lower Boise River is listed as water quality limited because of sediment. Cold water biota is a designated use for the entire lower Boise River from Lucky Peak Dam to the Snake River. Salmonid spawning is a designated use from Lucky Peak Dam to Caldwell, and it is an existing use from Caldwell to the Snake River.

Sediment-Related, General, and Aquatic Life Surface Water Quality Criteria

The following surface water quality criteria are from the Idaho Department of Health and Welfare Rules, Title 1, Chapter 2, "Water Quality Standards and Wastewater Treatment Requirements," Section 16.01.02-250.02(c) and (d), and Section 16.01.02-200.08.

Cold Water Biota

Turbidity, below any applicable mixing zone set by the Department of Health and Welfare, shall not exceed background turbidity by more than 50 nephelometric turbidity units (NTU) instantaneously or more than 25 NTU for more than 10 consecutive days.

Salmonid Spawning

During the spawning period and incubation for the particular species inhabiting the water, the intergravel dissolved oxygen concentration shall exhibit the following characteristics:

- One-day minimum of not less than 5.0 mg/L
- Seven-day average mean of not less than 6.0 mg/L

The time periods for salmonid spawning and incubation, as listed in the Idaho Water Quality Standards, are shown in Figure 1.

General (or Narrative)

Sediment shall not exceed quantities that impair designated beneficial uses.

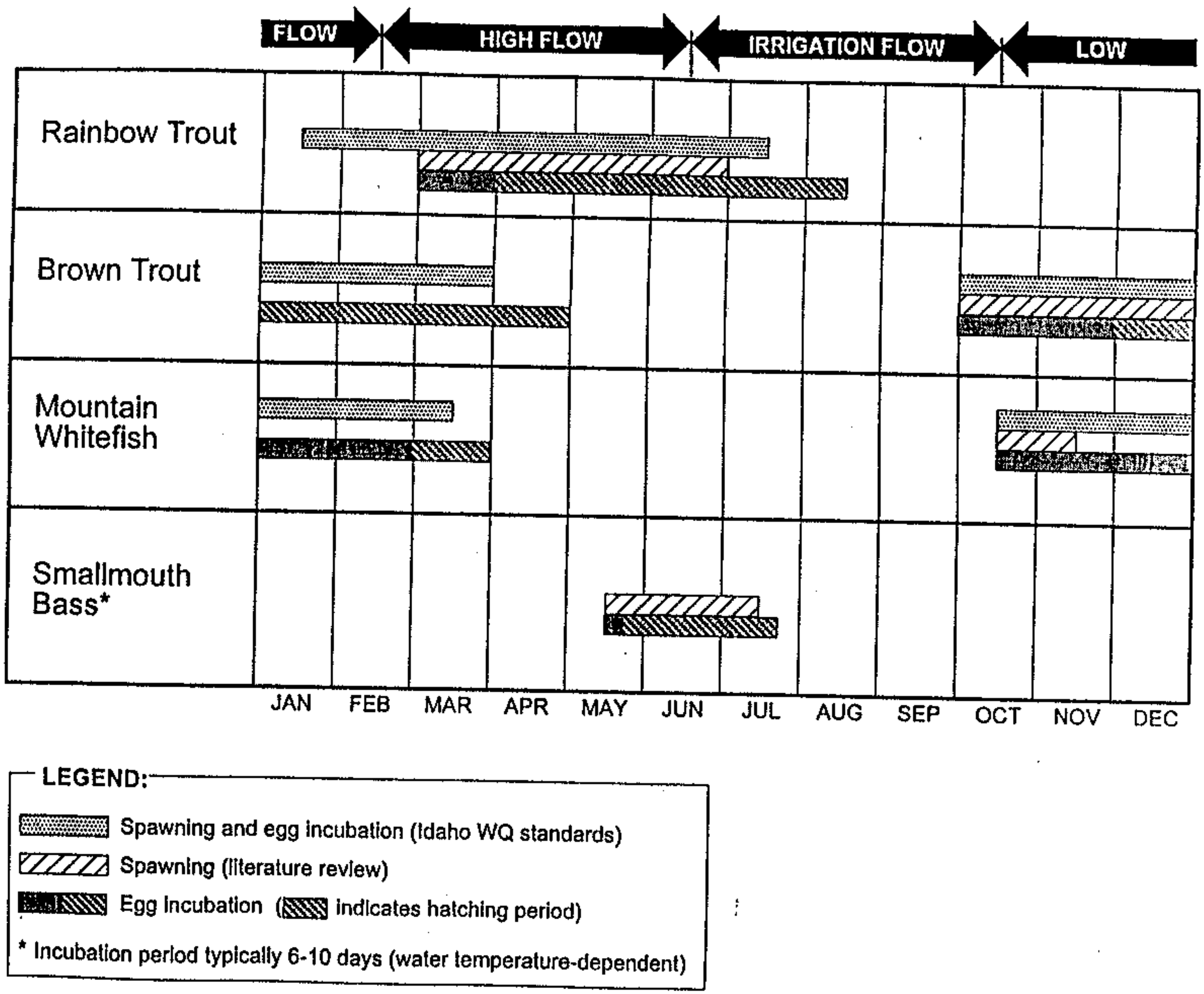


FIGURE 1
Spawning, Incubation, and Hatching Calendar

(Note: As part of the Lower Boise River Water Quality Plan, a literature review was conducted to determine the total suspended sediment (TSS) concentration limits for protection of the aquatic community in the lower Boise River. The recommended limits are a 50 mg/L geometric mean over 60 days (chronic), and an 80 mg/L geometric mean over 14 days (acute). See Appendix A for the basis of this recommendation.)

Summary of Existing Conditions

Background Information

An investigation of sediment in the river environment may involve characterizing either the water column or substrate conditions or both. Common measurements or indices used to quantify the sediment condition of either media follows:

Indices	Media
TSS concentration	Water column
Bed load sediment concentration	Water column/Substrate interface
Sediment particle size distribution	Water column or substrate
Embeddedness	Substrate
Intergravel dissolved oxygen concentration (on direct measurement of substrate quality for spawning)	Substrate

Water Column Sediment

Mass-Based. Sediment in the water column is typically classified by mode of transport—either suspended load or bed load. Suspended load refers to the material moving in suspension and sustained in the water column by turbulence or in colloidal suspension. Bed load is the coarse material moving in continuous or intermittent contact with the bed. Sediment load (either suspended or bed) is derived from sediment concentration and river discharge.

Turbidity. Turbidity is an optical property of water containing suspended material of unknown absolute concentration. Following are two citations presented by MacFarland and Peddicord (1980) that describe properties of turbidity:

- There is no predictable relationship between turbidities produced by equal mass concentrations of different materials (Pickering 1976).
- ...turbidity could be related to the mass concentration of particles only when the particles are of a uniform physical and chemical nature and instruments are calibrated against weighed samples (Kunkle and Comer 1971).

Substrate

Sieve analyses are used to develop particle (grain)-size distributions (PSDs) that describe the physical composition of a sediment sample. PSDs generated from sieve analyses represent the cumulative dry weight of the sample in various size fractions—boulder, cobble, gravel, sand, silt, and clay. Pebble count procedures are used in the field to develop PSDs based on a cumulative frequency distribution rather than a cumulative weight distribution.

Various indices can be computed from PSDs that reflect the quality of the substrate for a variety of aquatic uses such as spawning and rearing habitat, invertebrate production, and cover. Examples of such indices include the following:

- Median (D_{50}) particle size (Garde and Ranga Raju 1977)
- Geometric mean particle size (Platts and Shirazi 1979; Sowden and Powder 1985)
- Fine to coarse ratio (Dysart et al. 1973)
- Percent fines (Young et al. 1991; Adams and Beschta 1980; Sowden and Powder 1985)
- Fredle index (Lotspeich and Everest 1981; Sowden and Powder 1985)
- Gravel size (Witzel and MacCrimmon 1980)
- Percent composition of a given particle size class (Miller 1992)

Permeability is another measure of substrate quality (Chapman 1988); however, it can be obtained without a PSD.

Embeddedness, an optical measure that does not require a PSD, is the amount of fine sediment that is deposited in the interstitial space between larger substrate particles. For example, 30 percent cobble embeddedness means 30 percent of the cobble surface is fixed into surrounding sediment.

Significance of Flow as it Relates to Sediment

Flow, or discharge, is an important variable for studying sediment conditions in a river. The study of sediment transport is complex; however, two basic concepts should be understood:

- Sediment loads are a function of flow and sediment concentration (load = flow x concentration).

- Many variables other than flow influence sediment transport.

Velocity, for instance, is an important sediment transport parameter that is related to both flow and river-channel geometry. At any given flow, the sediment transport capacity can be different, depending on a number of variables such as channel geometry, channel slope, mean flow velocity, local velocity, particle size, and fluid density. Thus, variables other than flow are necessary for studying sediment transport problems such as incipient sediment motion, scour, armoring, and sediment deposition—all of which affect substrate quality for aquatic life purposes; however, only flow and sediment concentration are required to measure sediment loads in the water column.

Since flow and available TSS concentration data for the lower Boise River have been field-sampled (as opposed to modeled), no other information is required for computing water column sediment loads associated with the data. However, solutions to sediment transport problems, such as scour and deposition, cannot be determined from only flow and sediment concentration.

Lower Boise River Flow Regime

The flow regime in the lower Boise River changes on a seasonal basis in response to discharge requirements of the upstream reservoirs and the instream demands for irrigation. The flow regime can be partitioned into three predominant hydrologic seasons: high flow, irrigation flow, and low flow. The dates that define each period are somewhat arbitrary and, in general, are intended to encompass the flow characteristics of that period. But because the system is dynamic, some overlap was expected. Low flow corresponds to flows occurring from October 15 through February 14, the period of lowest flow for the lower Boise River. February 15 through June 14 marks the high-flow season as the reservoir pool levels peak and operators initiate discharge to adjust for snowmelt runoff, and to provide water for the beginning of irrigation season (around April 15). Flows occurring from June 15 through October 14 represent the irrigation-flow season, a period of more stable flows, involving diversions and returns to the river.

Lower Boise River Data

Monitoring Locations and Dates

Water Column Sediment. TSS concentrations, turbidities, and sediment loads were measured at four (water quality) locations along the main stem lower Boise River: 1) below Diversion Dam; 2) Glenwood Bridge; 3) Middleton; and 4) Parma. TSS concentrations and sediment loads (no turbidities) were measured at the mouth of 12 tributaries, upstream of any main stem backwater influence. The 12 tributaries are listed here in order of upstream to downstream location:

Tributary Name	Location Relative to Main Stem Monitoring Locations
Eagle Drain	Between Glenwood Bridge and Middleton
Thurmon Drain	Between Glenwood Bridge and Middleton
Fifteenmile Creek	Between Middleton and Parma
Mill Slough	Between Middleton and Parma
Willow Creek	Between Middleton and Parma
Mason Slough	Between Middleton and Parma
Mason Creek	Between Middleton and Parma
E. Hartley Drain	Between Middleton and Parma
W. Hartley Drain	Between Middleton and Parma
Indian Creek	Between Middleton and Parma
Conway Gulch	Between Middleton and Parma
Dixie Drain	Between Middleton and Parma

Sampling dates for all locations and parameters are listed in Appendix B.

Substrate. Pebble counts and percent embeddedness were measured at three locations in the main stem lower Boise River during a Level I and II habitat survey (Meador et al. 1993) in November 1997 and January 1998. The three locations (relative to the water quality monitoring locations) were: 1) below Eckert Road (between Diversion Dam and Glenwood Bridge); 2) Middleton; and 3) at the mouth (downstream of Parma).

Flow. Daily average flows were obtained from published U.S. Geological Survey (USGS) records for the gages located at each of the four main stem water quality stations. Daily average flows for the 12 tributaries were obtained from the Idaho Department of Water Resources. Additionally, instantaneous flow measurements were performed at all sampling locations whenever TSS concentrations were measured.

Flow data from water year 1990 through current records were used to generate flow statistics for all the sampling locations. Statistics generated from flow records beginning with water year 1955 and 1990 were found to be comparable at each of the main stem USGS gages. Figure 2 illustrates that annual discharges during the 1990s span the entire range of historical annual discharges measured at the Boise River USGS gage (13202000) located at Lucky Peak Dam. Because of the comparable statistics, and the fact that the majority of water quality data were collected during the 1990s, and because flows from this time period are more reflective of current land use practices and development, only the 1990s flow statistics were used for computing seasonal TSS loads.

TSS Concentrations, Median Flows, and TSS Loads

Appendix B contains the sampling date, instantaneous discharge, turbidity, TSS concentration, and sediment load (computed from instantaneous discharge) for all monitoring locations as reported by the USGS. Appendix C contains the normal and log-transformed TSS concentration data for all monitoring locations and seasons.

The "Parma (Historical)" data set, shown in Appendix C, consists of intermittent data from 1974 through 1997 (see the dates in Appendix B). The "Parma 1990s" data set consists of data from the 1990s only. Because the summary statistics generated from the historical data are very similar to the 1990s data, and because the 1990s data are more representative of current land use practices, and the time period is consistent with that used for the flow analysis, statistics from the "Parma 1990s" data are presented and analyzed hereafter.

Applying the statistical methodology described in Appendix E of the *Technical Support Document For Water Quality-based Toxics* (USEPA 1991) to the main stem data (minimum sample size, n = 30), the TSS concentrations were found to be lognormally distributed. The TSS concentration data for the tributaries (smaller n values) were assumed to be lognormally distributed. Therefore, the statistics (geometric mean and 90th percentile) used to describe the TSS concentration data will be based on the log-transformed data shown in Appendix C.

When the data were split into three seasons, the resulting sample size at seven tributaries was <4 during the irrigation season. Four of the same tributaries have a sample size <4 during the low-flow season. However, because the TSS concentration data exhibited a

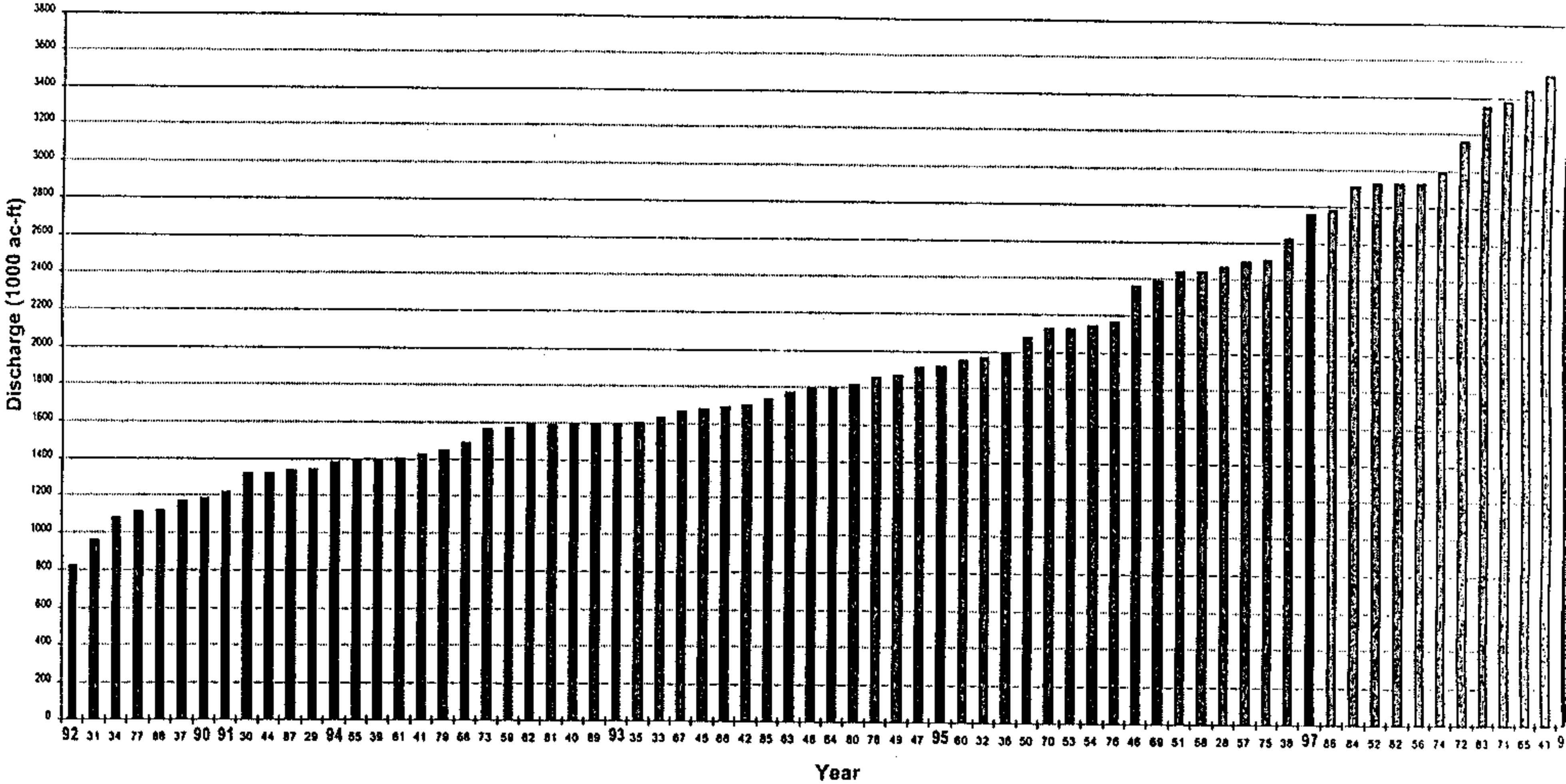


FIGURE 2
Ranking of Total Annual Discharge at USGS Station Boise River NR Boise (1928-1997) Located at Lucky Peak

seasonal trend at the other nine locations (where n≥4), a relationship was developed from these tributaries and used to estimate the irrigation- and/or low-flow season geometric mean and 90th percentile concentrations where needed (Appendix D). The complete list of sample sizes, geometric means, and 90th percentile TSS concentrations for all monitoring locations is presented in Appendix D.

Note that a location named "Hartley (combined)" is included in Appendix D. This location represents the water quality just downstream of the confluence of East Hartley Drain and West Hartley Gulch. TSS concentration data for this location were generated using a mass balance of the daily average flows and TSS concentrations measured on the same day in East Hartley Drain and West Hartley Gulch (mass balance based on n = 15).

Geometric Mean and 90th Percentile TSS Concentrations. Figures 3 and 4 illustrate the seasonal geometric mean and 90th percentile TSS concentrations, respectively, in the main stem lower Boise River. Statistics for the data, undivided by season, are presented for comparison. Both figures illustrate the recommended TSS concentration limits (Appendix A) for supporting the narrative sediment criteria listed above.

The following conclusions can be drawn from these two figures:

- Low-flow season geometric mean and 90th percentile TSS concentrations do not exceed 42 mg/L in the main stem.
- Geometric mean and 90th percentile TSS concentrations from Below Diversion Dam and Glenwood Bridge do not exceed 45 mg/L during any season.
- 50 mg/L TSS is exceeded at Parma during the high- and irrigation-flow seasons based on the geometric mean and 90th percentile concentrations and at Middleton during the high-flow season based on the 90th percentile concentration.

Figures 5 and 6 show the same parameters for the tributaries. Some conclusions that can be drawn from these figures are the following:

- TSS concentrations are lowest during the low-flow season (the only exceptions occur at Indian Creek and Willow Creek).
- In general, the TSS concentrations are higher in the tributaries than in the main stem.
- Mason Creek, Conway Gulch, and Fifteenmile Creek have the highest TSS concentrations during the high-and irrigation-flow seasons.

Median Flows. Figures 7 and 8 illustrate the seasonal median flows (computed from daily average flows) at the main stem and tributary sampling locations, respectively. A number of significant observations pertaining to Figure 7 follow:

- During the high- and irrigation-flow seasons, the median flows decrease from a maximum at Below Diversion Dam to a minimum at Middleton, and then increase again between Middleton and Parma.
- Only during the low-flow season does the magnitude of the median flow increase in a downstream direction.

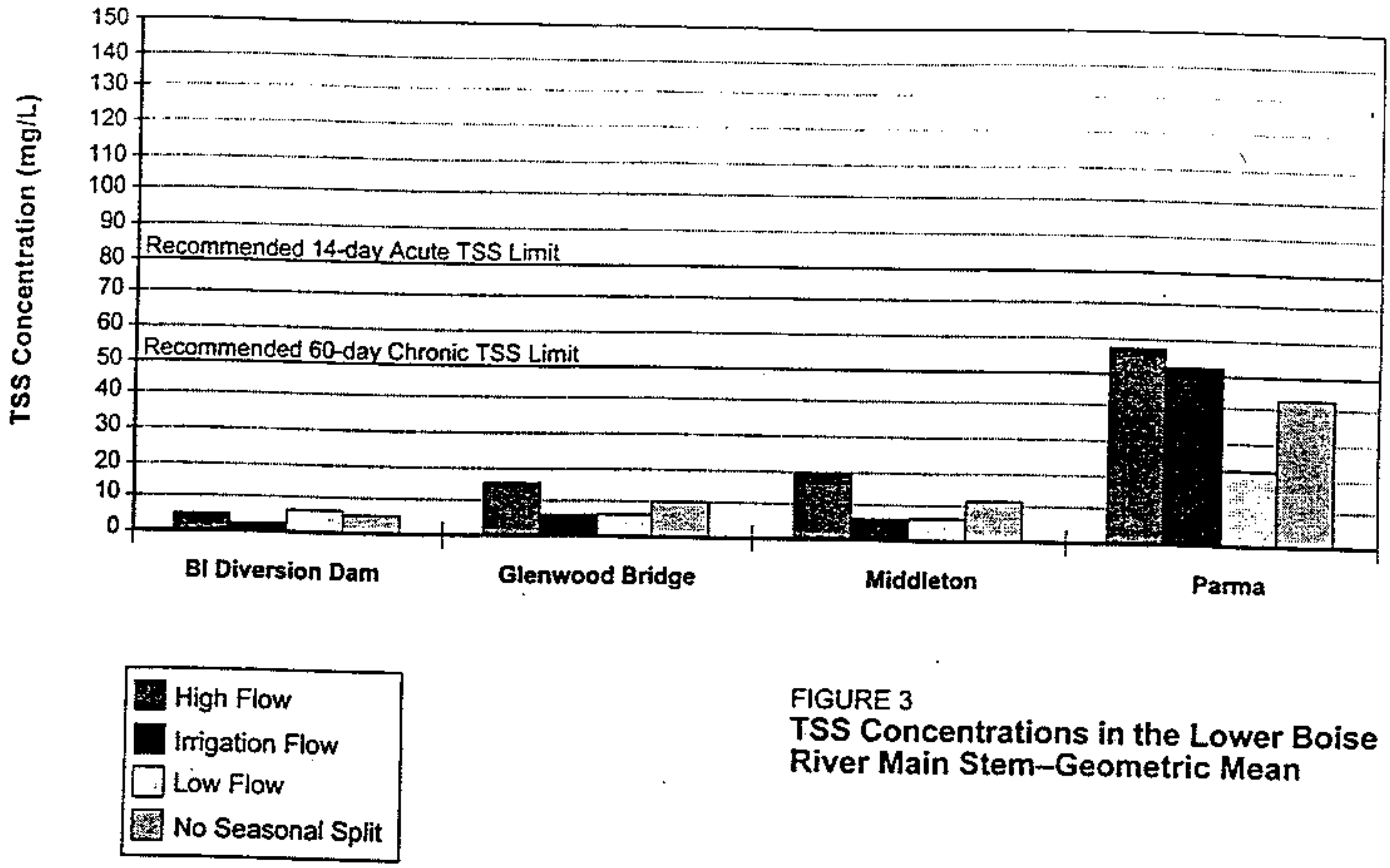


FIGURE 3
TSS Concentrations in the Lower Boise River Main Stem–Geometric Mean

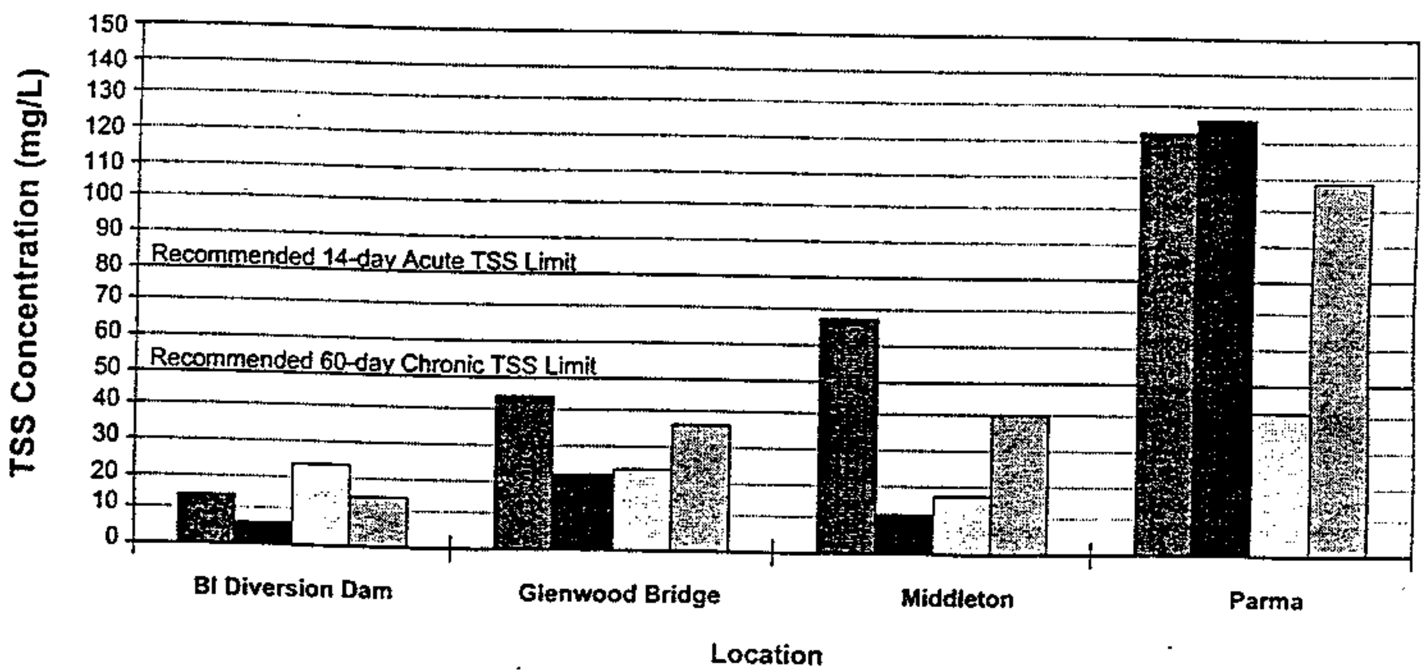


FIGURE 4
TSS Concentrations in the Lower Boise River Main Stem–90th Percentile

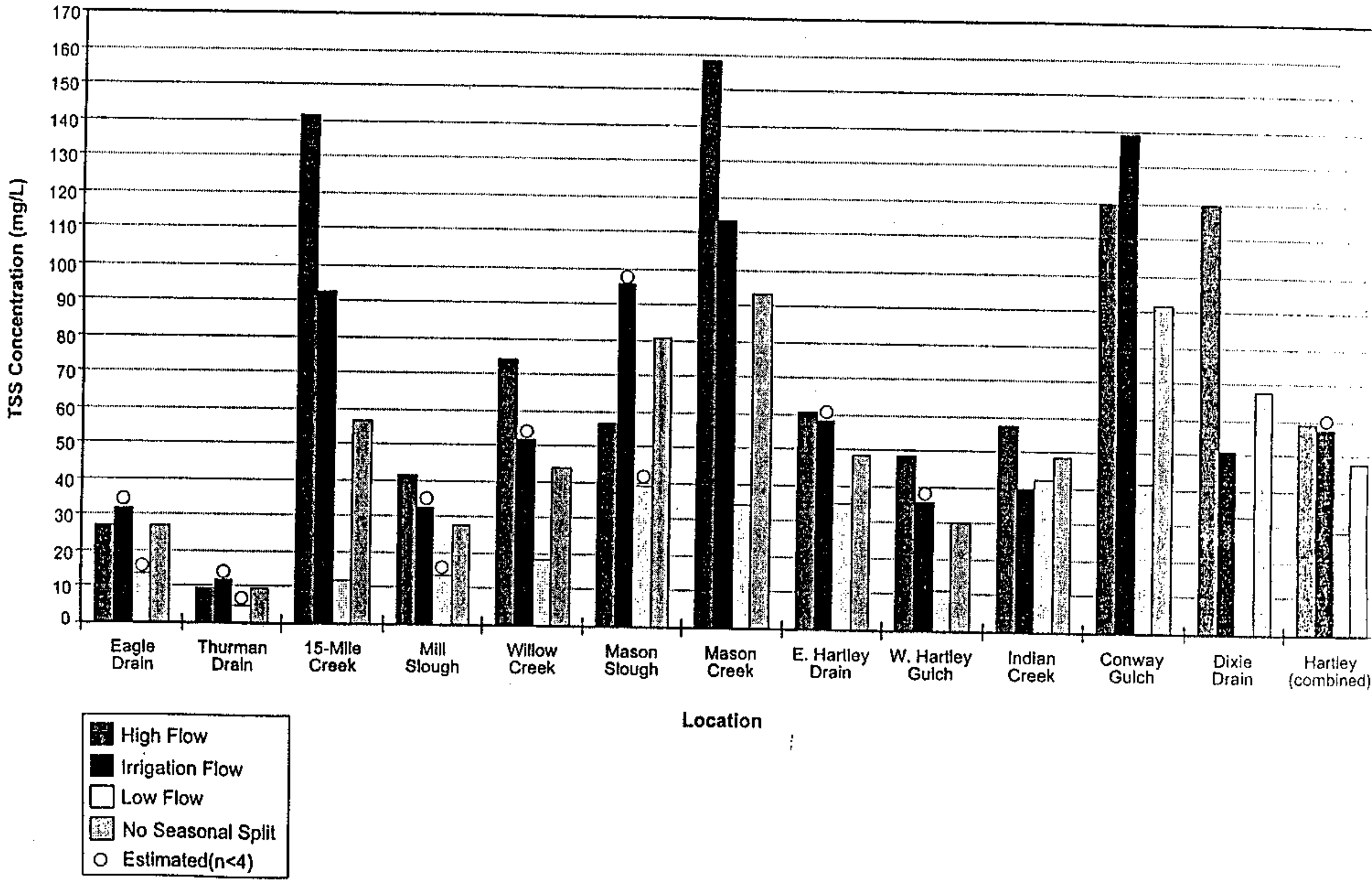


FIGURE 5
TSS Concentrations in the Lower Boise River Tributaries–Geometric Mean

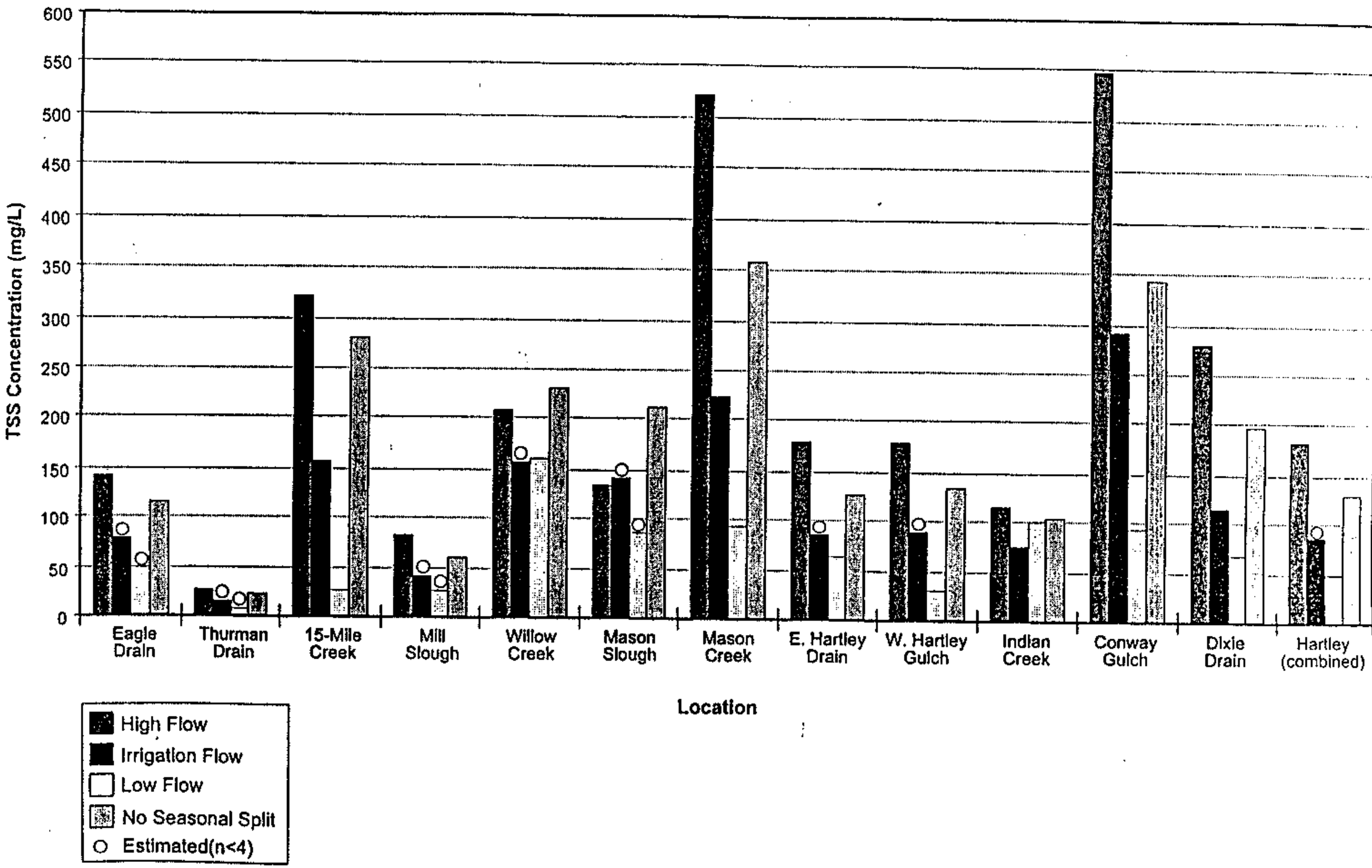


FIGURE 6
TSS Concentrations In the Lower Boise River Tributaries–90th Percentile

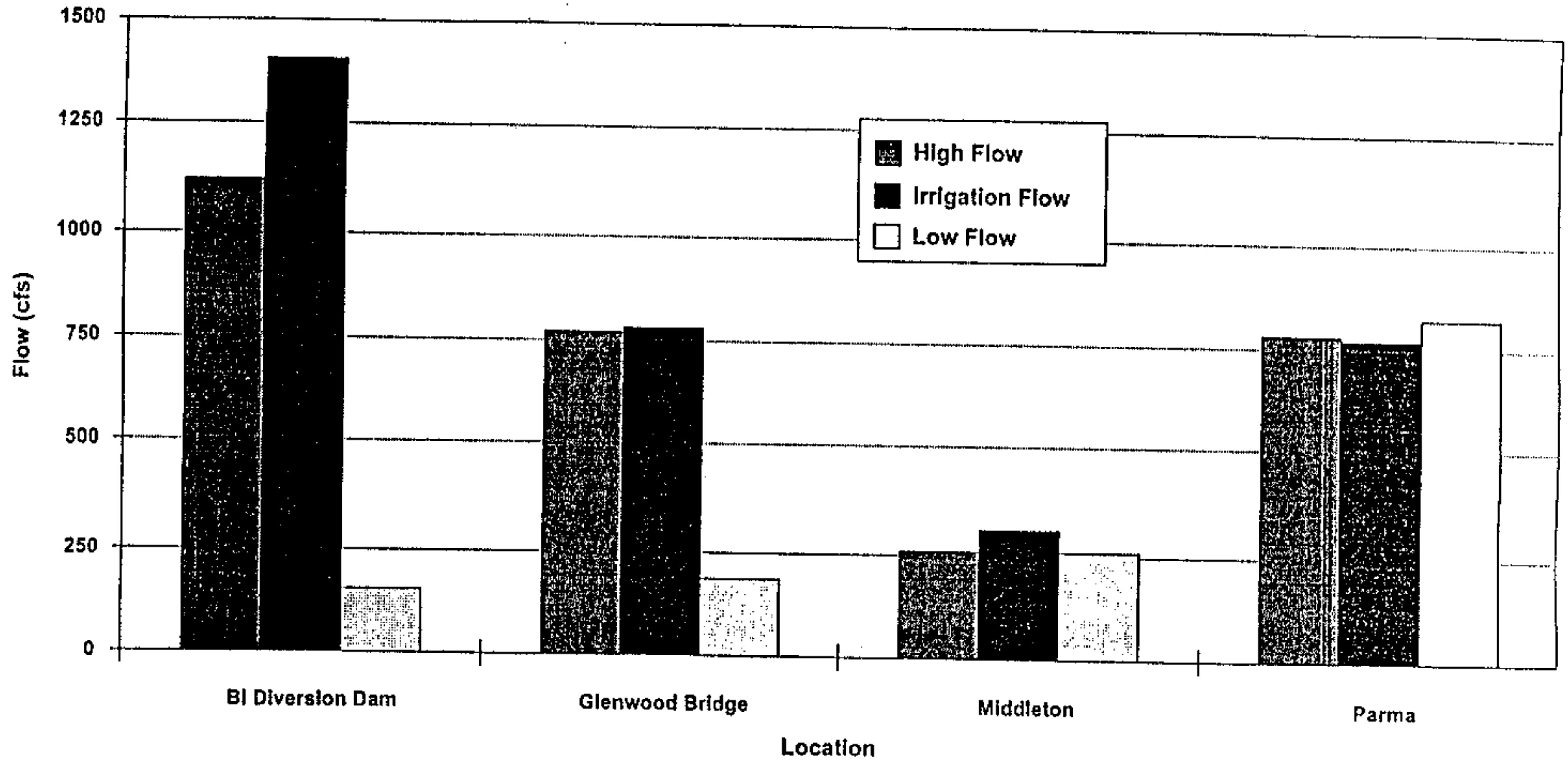


FIGURE 7
Lower Boise River Main Stem Median Flows

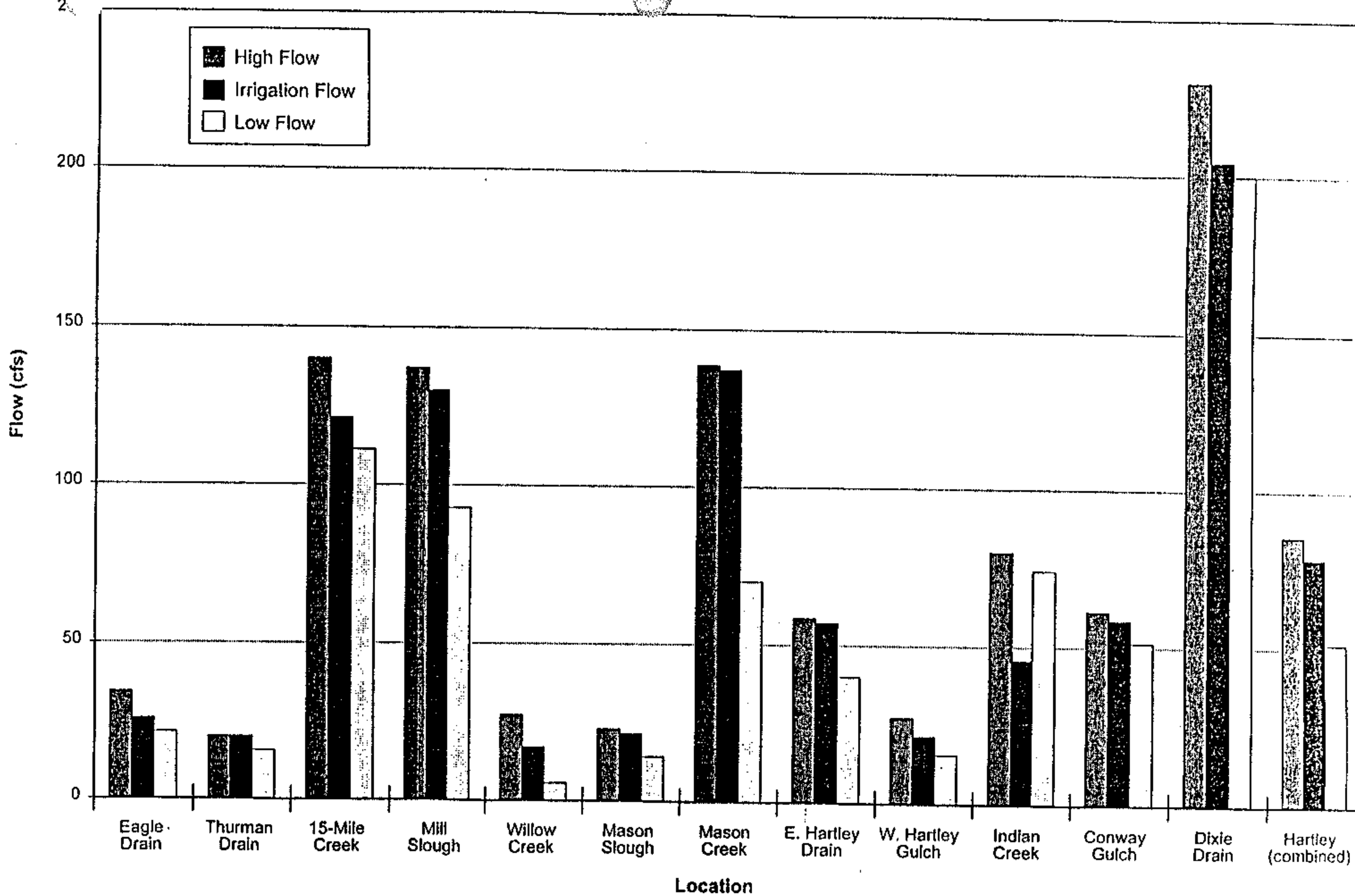


FIGURE 8
Lower Boise River Tributaries–Median Flows

- At the upper two stations, the median flows are significantly greater during the high- and irrigation-flow seasons compared to the low-flow season; however, there is essentially no seasonal difference in median flows at each of the lower two stations.

All three of these observations can be attributed, at least in part, to: 1) significant diversions during the high- and irrigation-flow seasons upstream of Middleton; and 2) significant return flows (via surface or groundwater) during all seasons downstream of Middleton.

Figure 8 shows that the tributaries with the highest median flows (in descending order) are as follows:

- Dixie Drain
- Fifteenmile Creek, Mill Slough, and Mason Creek (all similar in magnitude)
- Indian Creek and Hartley (combined)
- Conway Gulch

TSS Loads Based on Median Flows and Geometric Mean and 90th Percentile Concentrations. Main stem seasonal TSS loads are shown in Figures 9 and 10. TSS loads based on geometric means range from 4 (high-flow season) to 19 (irrigation-flow season) times higher at Parma than the upstream stations. During the high- and irrigation-flow seasons, when median flows are comparable at Parma and Glenwood, TSS loads based on geometric means range from 4 to 7 times higher at Parma. Based on the significant difference in flows at Middleton and Parma, and the relatively high TSS concentrations at Parma, the largest increase in TSS load—between any to main stem monitoring locations—occurs between Middleton and Parma during the high- and irrigation-flow seasons. The trends are similar based on TSS loads computed from the 90th percentile concentration.

Figures 11 and 12 illustrate TSS loads in the 12 tributaries computed from median flows and geometric mean and 90th percentile concentrations, respectively. In terms of highest TSS loads, the three most significant tributaries are the following:

- Dixie Drain
- Mason Creek
- Fifteenmile Creek

These three are followed by Conway Gulch, Mill Slough, and Hartley (combined). Based on the TSS loads computed from the geometric mean concentration, the load at Conway Gulch is approximately four times lower than the high-flow season load at Dixie Slough and the irrigation-flow season load at Mason Creek. The low-flow season TSS loads are lower than both the high- and irrigation-flow season loads at all locations except Indian Creek.

For each of the three seasons, Figures 13, 14, and 15 show the main stem, measured TSS loads compared to those computed from the recommended TSS concentration limits (Appendix A), and median flows. The only location and seasons for which the 50 mg/L target load is exceeded by the measured load—based on the geometric mean concentration—is at Parma during the high- and irrigation-flow seasons. Similarly, only during the high-flow season at Middleton and the high- and irrigation-flow seasons at Parma does the measured load—based on the 90th percentile concentration—exceed either the 50 mg/L or 80 mg/L target loads.

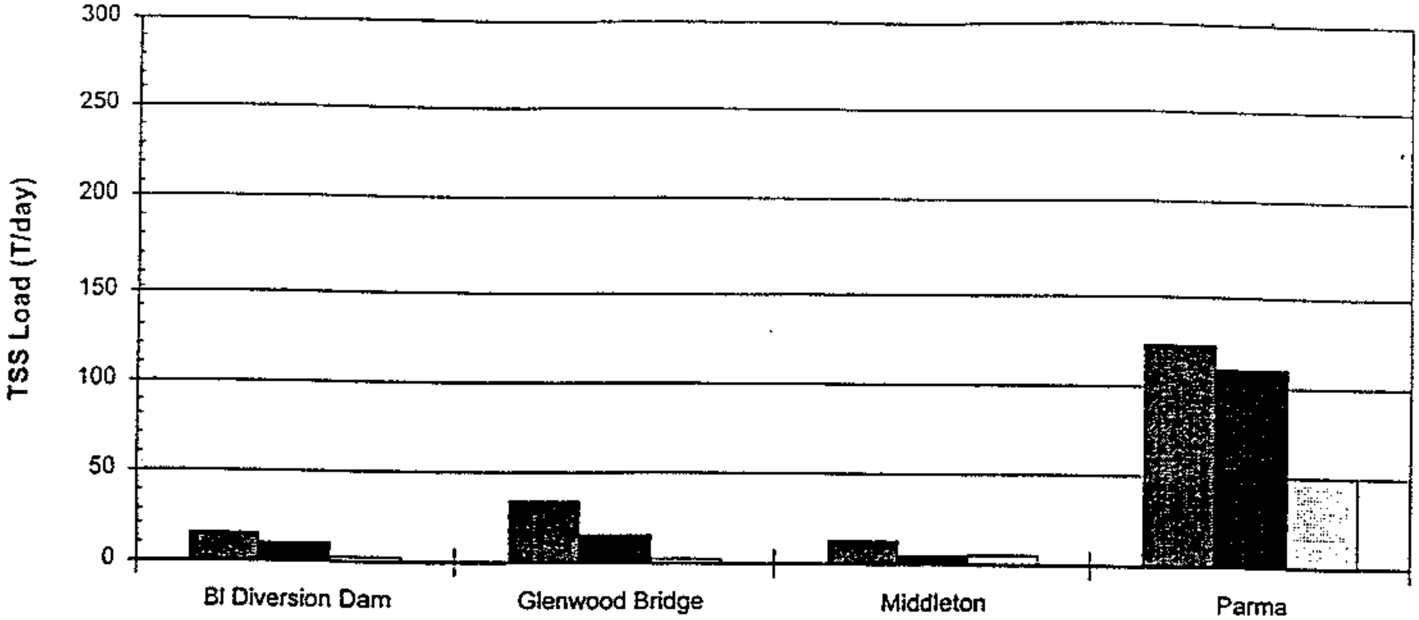
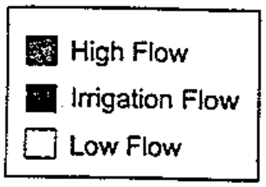


FIGURE 9
TSS Loads in the Lower Boise River Main Stem–Geometric Mean Concentration and Median Flow



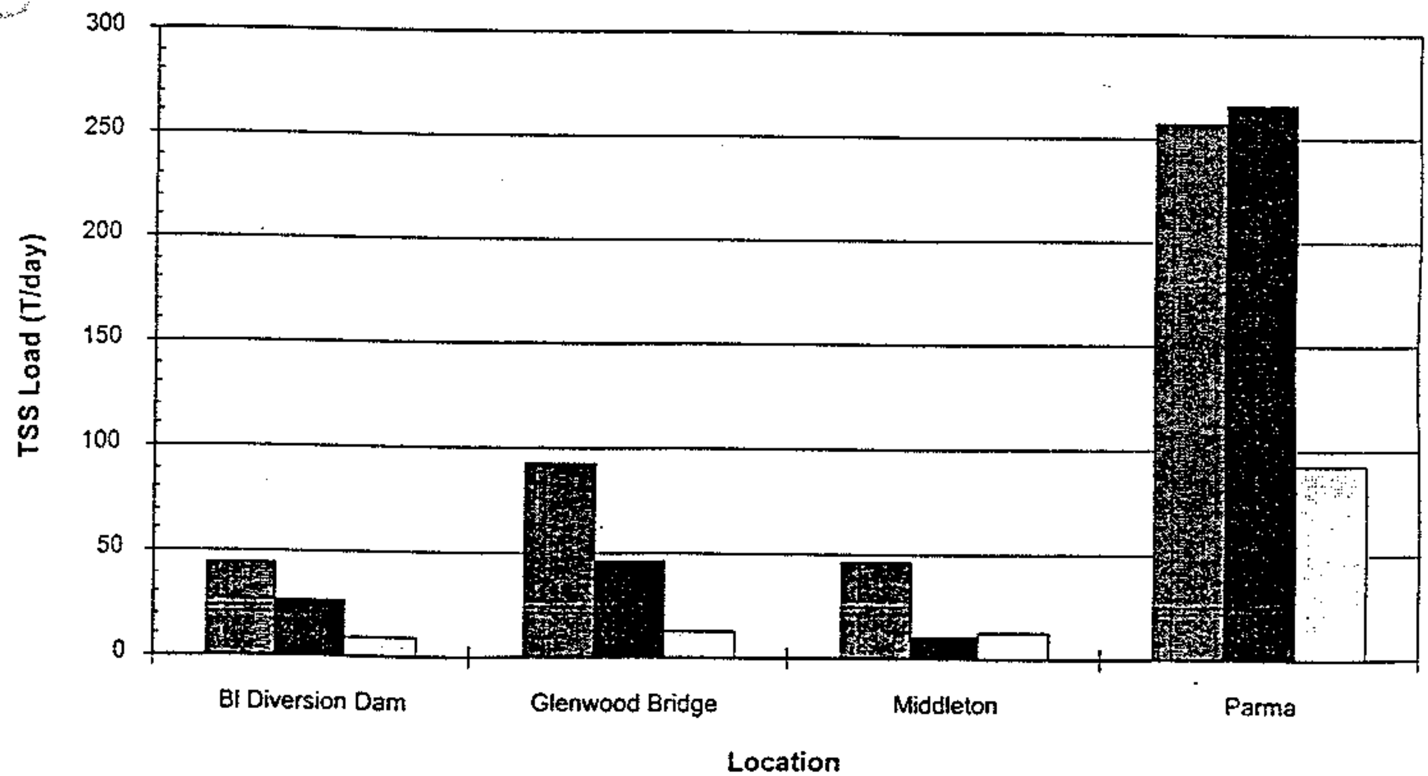


FIGURE 10
TSS Loads in the Lower Boise River Main Stem–90th Percentile Concentration and Median Flow

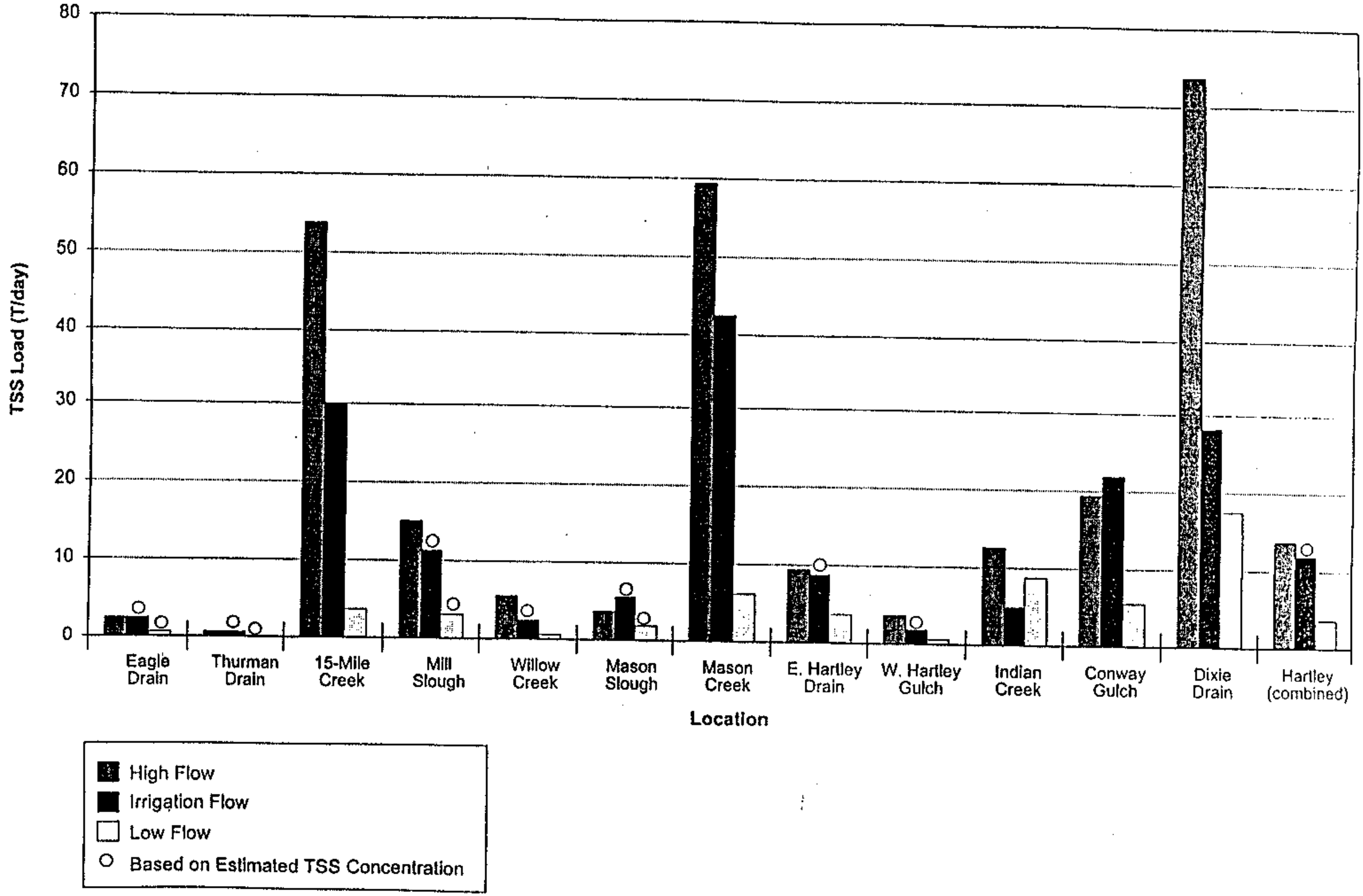


FIGURE 11
TSS Loads in the Lower Boise River Tributaries–Geometric Mean Concentration and Median Flow

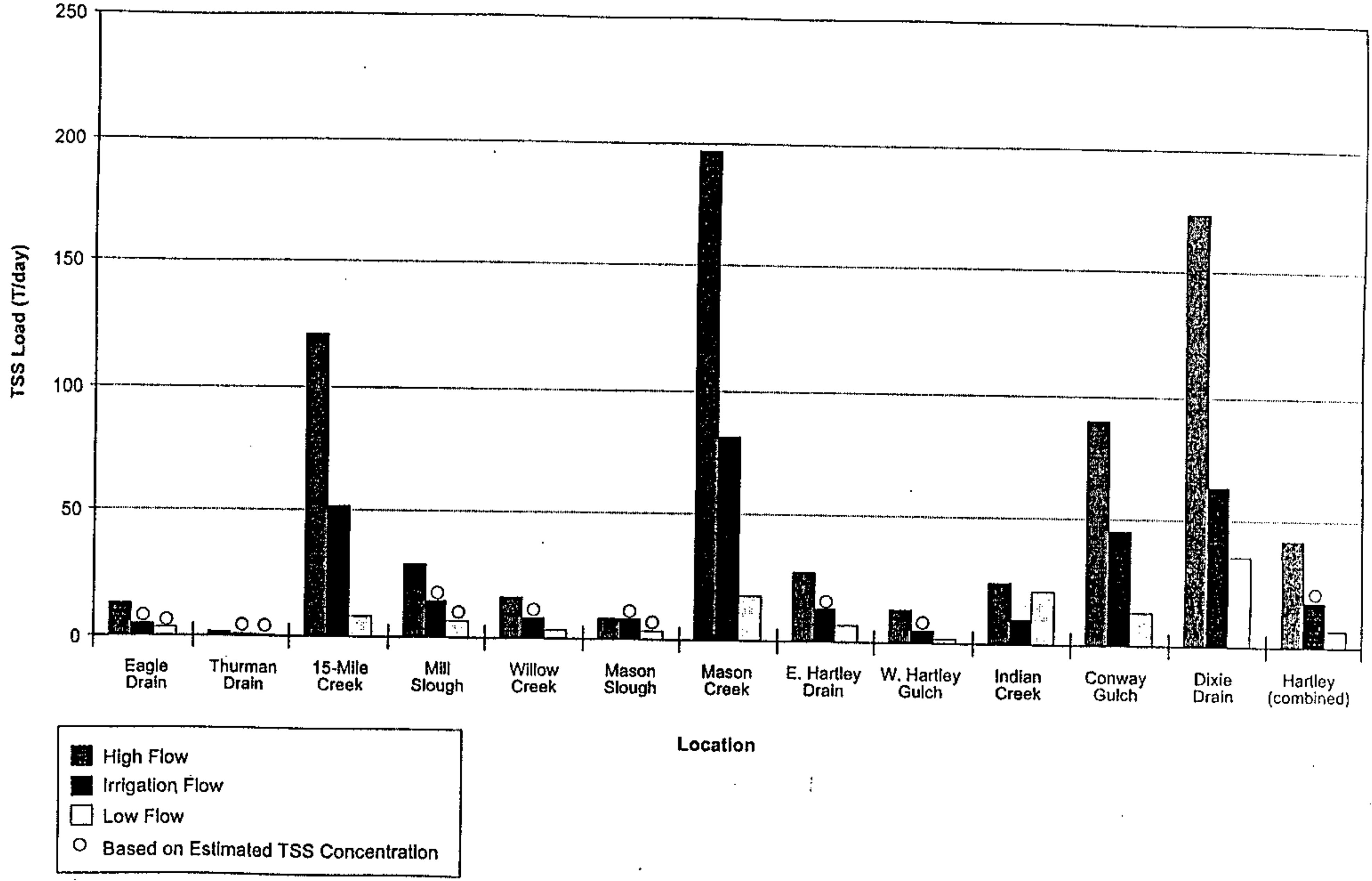


FIGURE 12
TSS Loads in the Lower Boise River Tributaries–90th Percentile Concentration and Median Flow

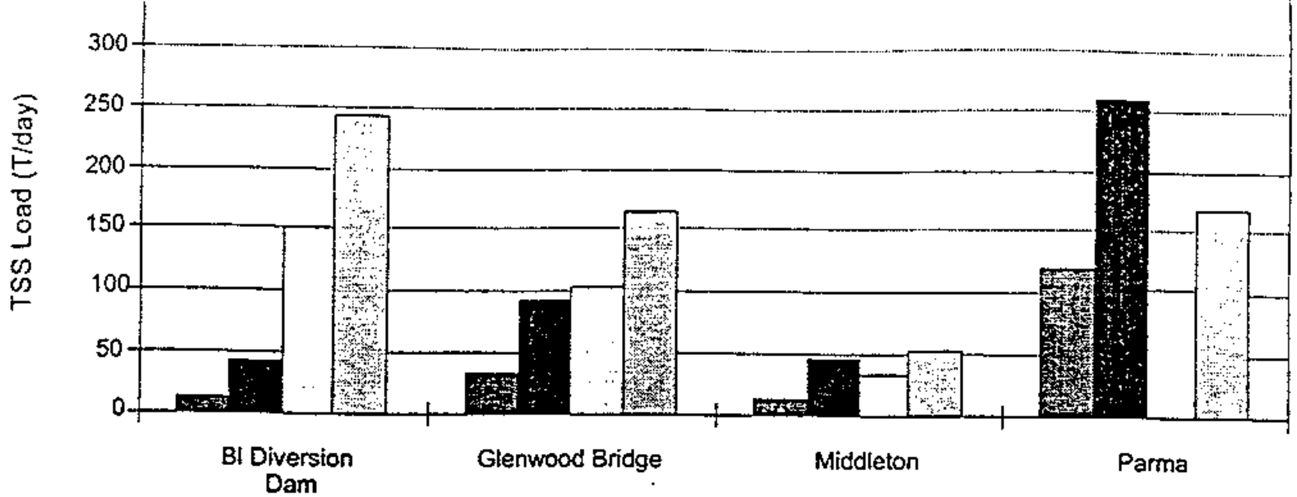


FIGURE 13
Lower Boise River Main Stem TSS Loads High-Flow Season–Median Flow and Existing and Target Concentrations

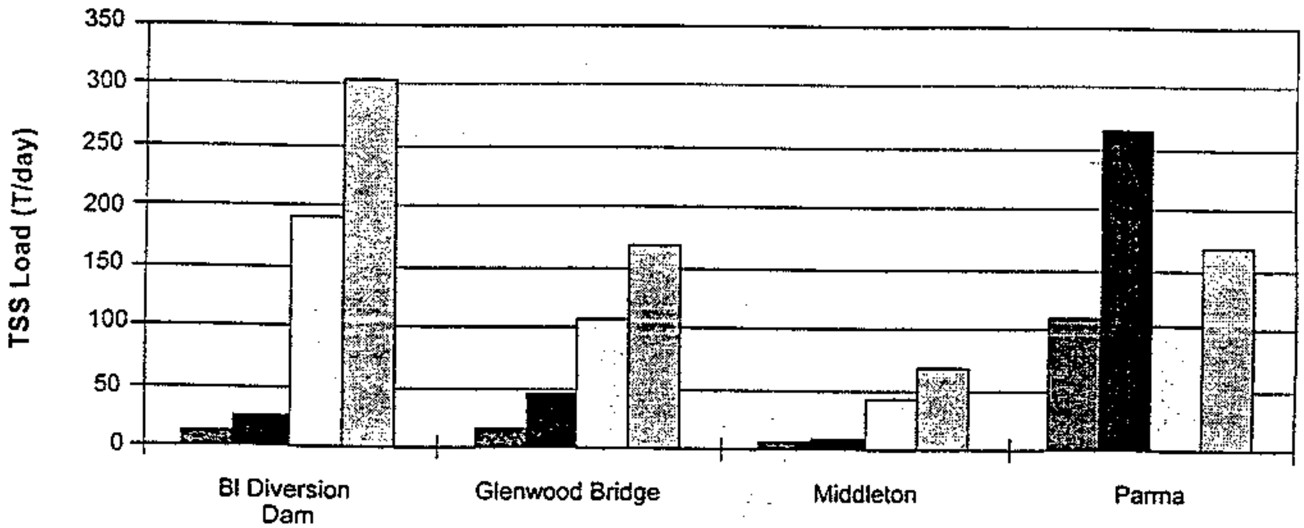


FIGURE 14
Lower Boise River Main Stem TSS Loads Irrigation-Flow Season–Median Flow and Existing and Target Concentrations

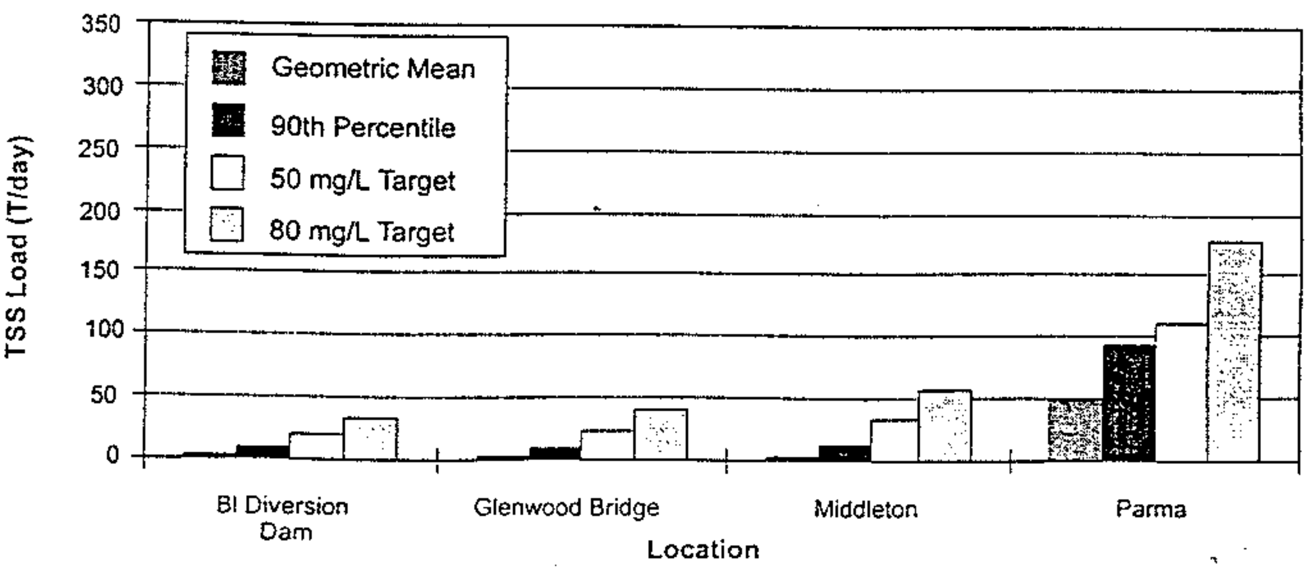


FIGURE 15
Lower Boise River Main Stem TSS Loads Low-Flow Season–Median Flow and Existing and Target Concentrations

Turbidity

Main stem seasonal averages and ranges of turbidity are shown in Figures 16, 17 and 18. Turbidities average less than 5 NTU at the three upstream monitoring locations during all seasons. Parma averages less than 15 NTU during all three seasons. The maximum turbidity of 37 NTU was measured at Parma during the irrigation-flow season.

Figure 19 presents main stem turbidity and TSS concentration data pairs that were sampled on the same day. A linear regression line through the Parma data ($r^2 = 0.66$) indicates that at this location, relatively low turbidities are associated with relatively high TSS concentrations. The State water quality criteria for cold water biota states that turbidity shall not exceed background by more than 50 NTU instantaneous or more than 25 NTU for more than 10 consecutive days. As mentioned above, the maximum turbidity measured in the lower Boise River is 37 NTU. At Parma, based on the regression shown in Figure 19, turbidities >25 NTU would be associated with TSS concentrations >100 mg/L. Because TSS concentrations >100 mg/L are not supportive of the narrative criteria (Appendix A), the existing turbidity standard is not protective of the aquatic life at Parma.

Substrate

Chapman and McLeod (1987) provide a detailed review of the relationship between percent embeddedness and fish densities in the Northwest. Although a variety of relationships (with varying degrees of significance) were found, in general, it could be said that salmonid densities tend to be lower in areas with 50 percent embeddedness or higher.

Figure 20 presents percent embeddedness estimates for the main stem lower Boise River. The mean percent embeddedness for the sampling locations near Middleton and the mouth of the Boise River is ≥ 50 percent. At the location below Eckert Road (between the Diversion Dam and Glenwood Bridge), the mean percent embeddedness ranged from 25 to 50 percent. Data in Figure 20 are based on one sampling event.

Lisle and Eads (1991) reported that thresholds of concern for fine sediment content vary between experiment, species, and grain size of fine sediment, but most commonly fall around 20 percent (see also: Witzel and MacCrimmon 1980; Maret et al. 1993; and Waters 1995). Based on the pebble count data presented in Figure 21, the 20 percent-fines threshold was exceeded in the Boise River near Middleton and the mouth during one event in December 1997 and January 1998, respectively. No silt-sized particles were found at the Eckert Road site; however, sand particles comprised 17 percent of the substrate. The remainder of the substrate at all three sites was comprised mainly of medium gravel to large cobble.

Although the only sediment-related measure pertaining to the salmonid spawning criteria is intergravel dissolved oxygen concentration, the two data sets presented here suggest that the substrate is not conducive to salmonid spawning, at least near Middleton and at the mouth of the river—although whitefish *may* be the exception since they are broadcast spawners. In addition, based on field studies at Rock Creek in south-central Idaho, Maret et al. (1993) determined that mean intergravel dissolved oxygen concentrations should exceed 8.0 mg/L in redds to ensure at least 50 percent survival during the pre-emergence stage. They determined for their study site that sediment with more than 15 percent fines may reduce intergravel dissolved oxygen concentrations to unacceptable levels for survival during incubation.

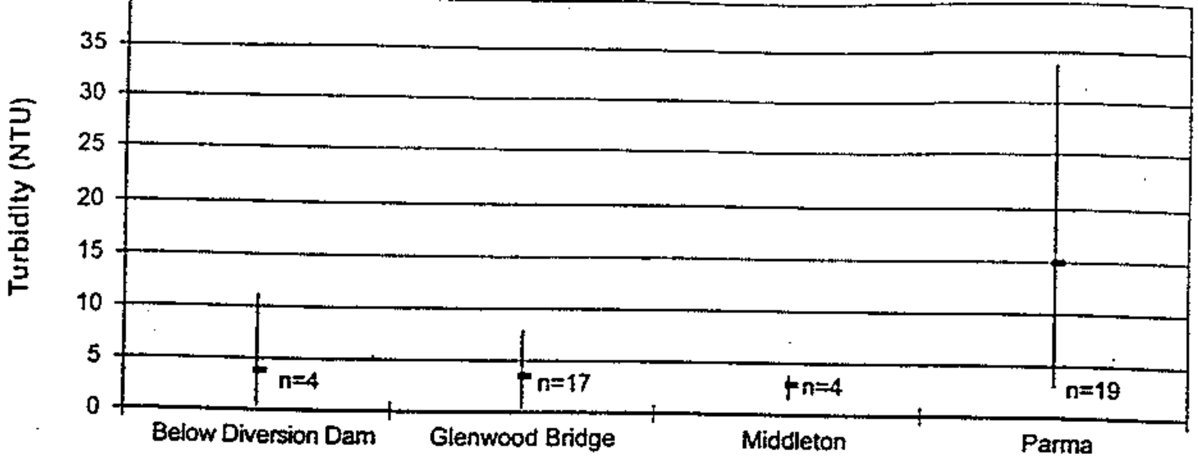


FIGURE 16
Lower Boise River Turbidity–Averages and Ranges During High-Flow Season

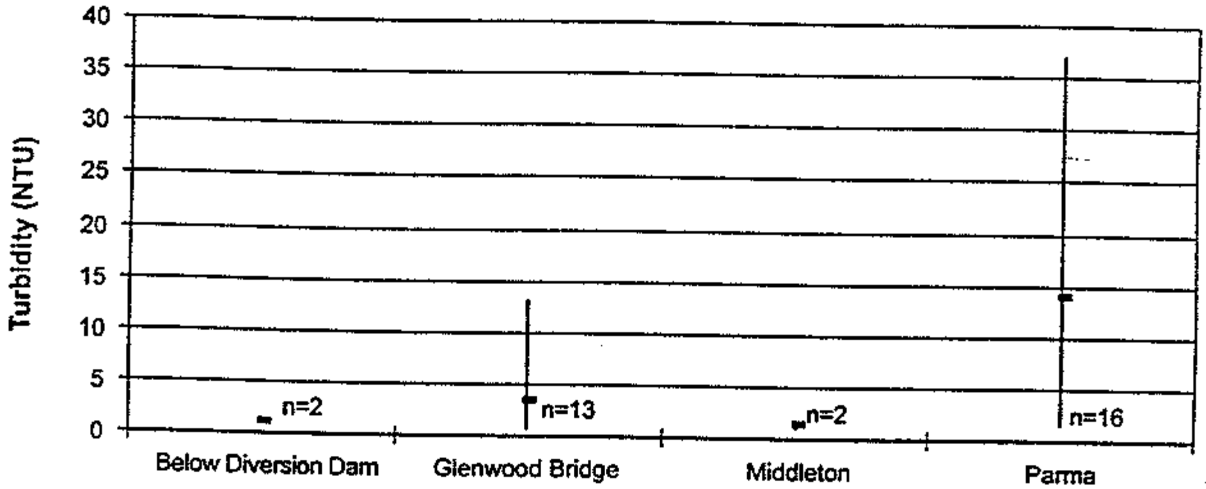


FIGURE 17
Lower Boise River Turbidity–Averages and Ranges During Irrigation-Flow Season

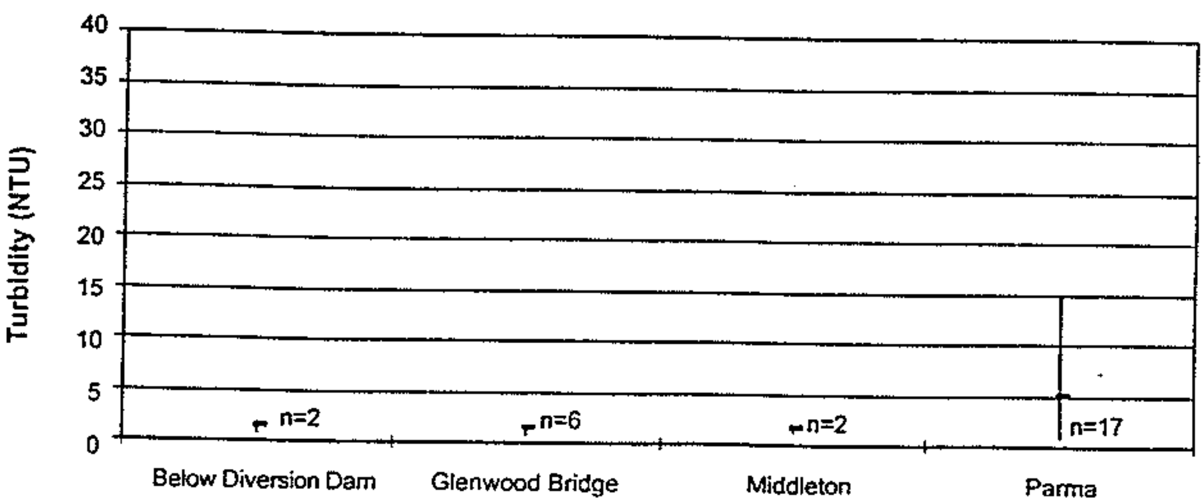


FIGURE 18
Lower Boise River Turbidity–Averages and Ranges During Low-Flow Season

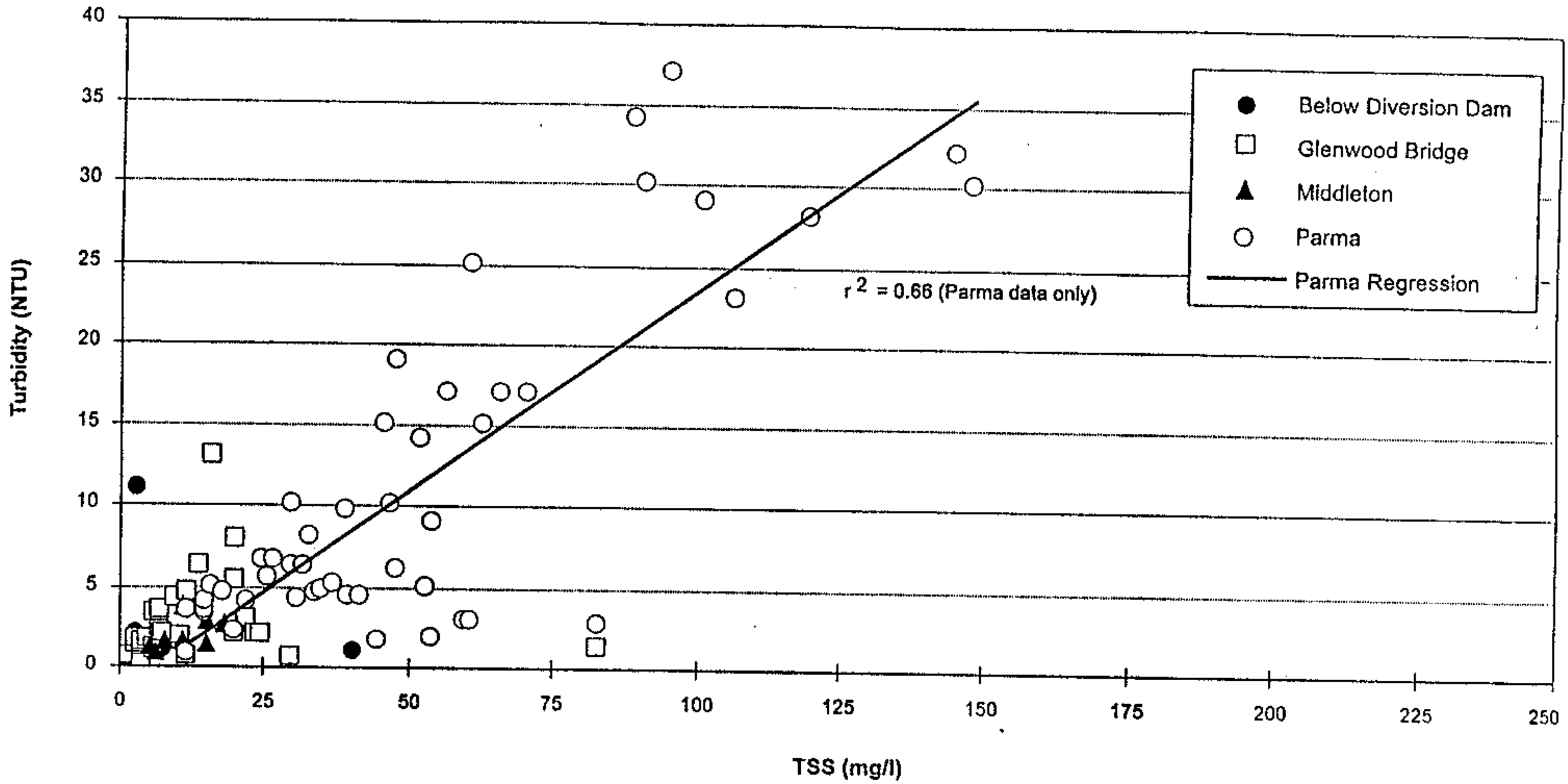


FIGURE 19
Lower Boise River Main Stem–
Turbidity Versus TSS Concentration

Boise River Below Eckert Road:

Station	Deepest Point	1/3	2/3	Mean	% Embeddedness (approx.)
Tran 1 (Deep Run)	2	2	2	2.0	
Tran 2 (Riffle)	3	4	3	3.3	
Tran 3 (Run/Pool)	4	2	2	2.7	
Tran 4 (Run/Pool)	2	3	2	2.3	
Transect 5 (Riffle)	3	4	4	3.7	
Transect 6 (Riffle)	4	4	2	3.3	
			Mean for Reach =	**2.9**	**25 - 50**

Boise River Near Middleton:

Station	Deepest Point	1/3	2/3	Mean	% Embeddedness (approx.)
Tran 1 (Riffle)	1	1	1	1.0	
Tran 2 (Run)	1	1	1	1.0	
Tran 3 (Riffle/Run)	2	2	2	2.0	
Tran 4 (Run)	1	1	2	1.3	
Transect 5 (Deep Run)	1	1	1	1.0	
Transect 6 (Run)	1	1	1	1.0	
			Mean for Reach =	**1.2**	**>=75**

Boise River Mouth:

Station	Deepest Point	1/3	2/3	Mean	% Embeddedness (approx.)
Tran 1 (Deep Run)	1	1	too deep	1.0	
Tran 2 (Run; 1/2 sampled)	too deep	1	0	0.5	
Tran 3 (Run; 1/2 sampled)	too deep	1	1	1.0	
Tran 4 (Riffle/Run; 3/4 sampled)	4	2	3	3.0	
Transect 5 (Riffle/Run)	2	3	3	2.7	
Transect 6 (Riffle/Run; 3/4 sampled)	4	4	4	4.0	
			Mean for Reach =	2.0	50 - 75

Embeddedness Rating:

0 <= GR; 1>= 75%; 2 = 50-75%; 3 = 25-50%; 4 = 5-25%; 5 <= 5%)

From: Lower Boise River Level I and II Habitat Survey Summary Statistics - USGS 1997.
Eckert Road and Middleton were sampled November 1997; Mouth was sampled January 1998.

FIGURE 20
Lower Boise River Substrate Embeddedness Data

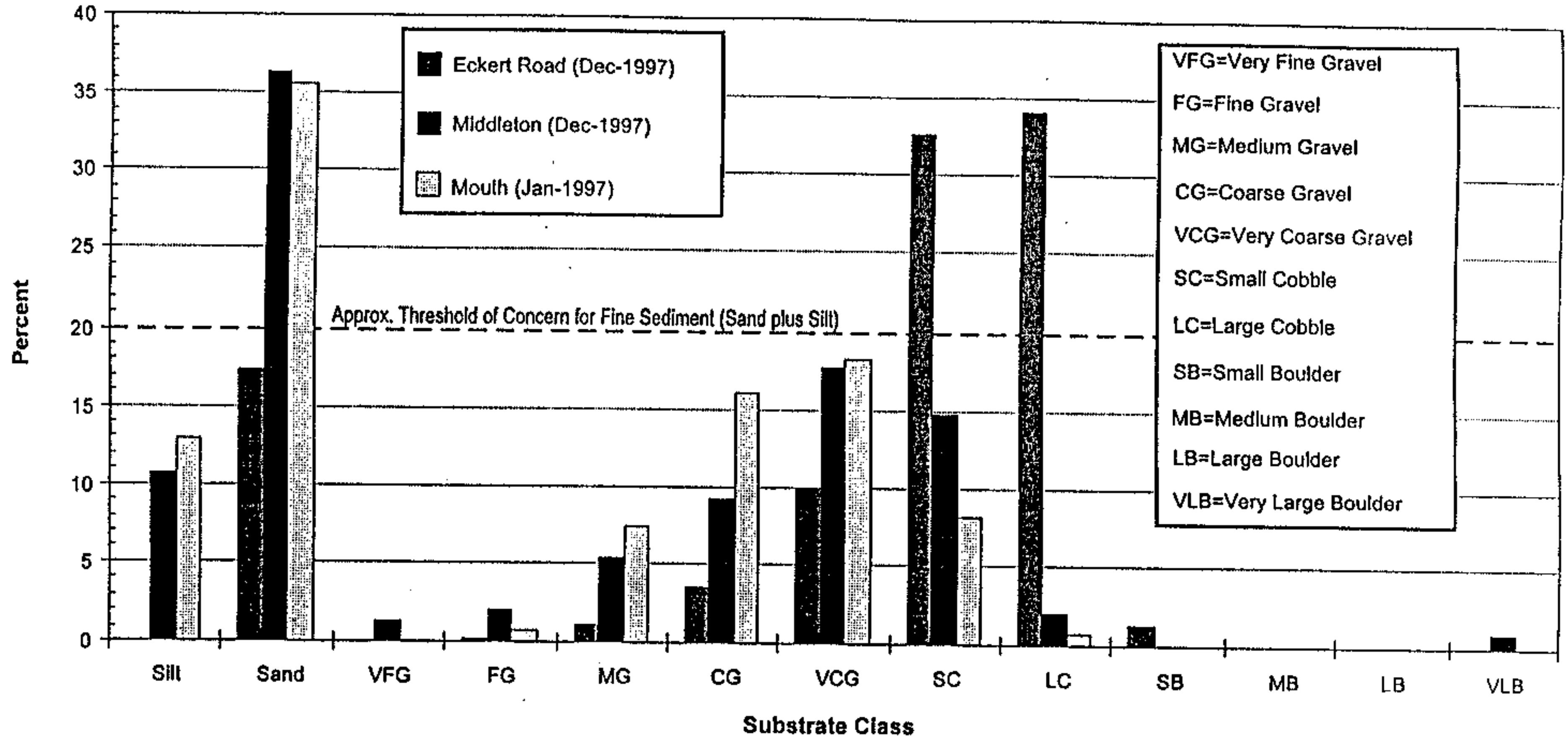


FIGURE 21
Lower Boise River Pebble Count Data

Data Gaps

Following are a list of data gaps:

- TSS duration data (i.e., the range of durations associated with various TSS concentrations)
- Bed load data
- Stream bank erosion rates
- Substrate and water column particle-size data
- Long-term channel geometry data
- Intergravel dissolved oxygen data
- Results from fish sampling efforts designed to collect larval and juvenile fish at specific locations throughout the main stem river and during the high- and irrigation-flow seasons

TSS duration data are important because duration of exposure influences the severity of ill effects of sediment on fish and their habitat (Appendix A). Although there seems to be somewhat of a "first flush" effect of TSS concentration in the lower Boise River (Figures 22 through 25), there is a poor relationship between concentration and discharge (Figure 26). Therefore, predicting the duration of elevated TSS concentrations at various discharges would be extremely difficult in the absence of TSS duration data.

Bed load is a means of sediment transport. If any bed load transport is occurring in the lower Boise River, sediment loads based only on TSS would underestimate the total sediment load. Morris and Fan (1997) reported that in many streams the bed material load constitutes less than 15 percent of the total load. From a biological standpoint, however, even small amounts of moving-sand bed load sediments have been shown to have a major impact on trout populations (Alexander and Hansen 1983).

Stream bank erosion is a potential source of sediment to the river. However, without measurements of stream bank erosion rates, it is difficult to estimate the significance of the source and its location.

Particle-size data are necessary to quantify the substrate quality for spawning and rearing habitat, as well as invertebrate production. Particle-size data are also integral to many sediment transport models and equations for predicting or quantifying armoring, scouring, and sediment deposition—all of which affect substrate quality for spawning.

Long-term channel geometry data can be useful for quantifying fish habitat (such as pool volume) or for quantifying spatial and temporal variations in scour and deposition rates. Measurement of intergravel dissolved oxygen concentration is another means of quantifying substrate spawning and rearing habitat quality.

Fish sampling methods geared toward the collection of larval and juvenile fish would help to better define the success of spawning for different species throughout the length of the river at different times of the year. Results from this type of sampling would provide a direct measure of salmonid (and other species) spawning success.

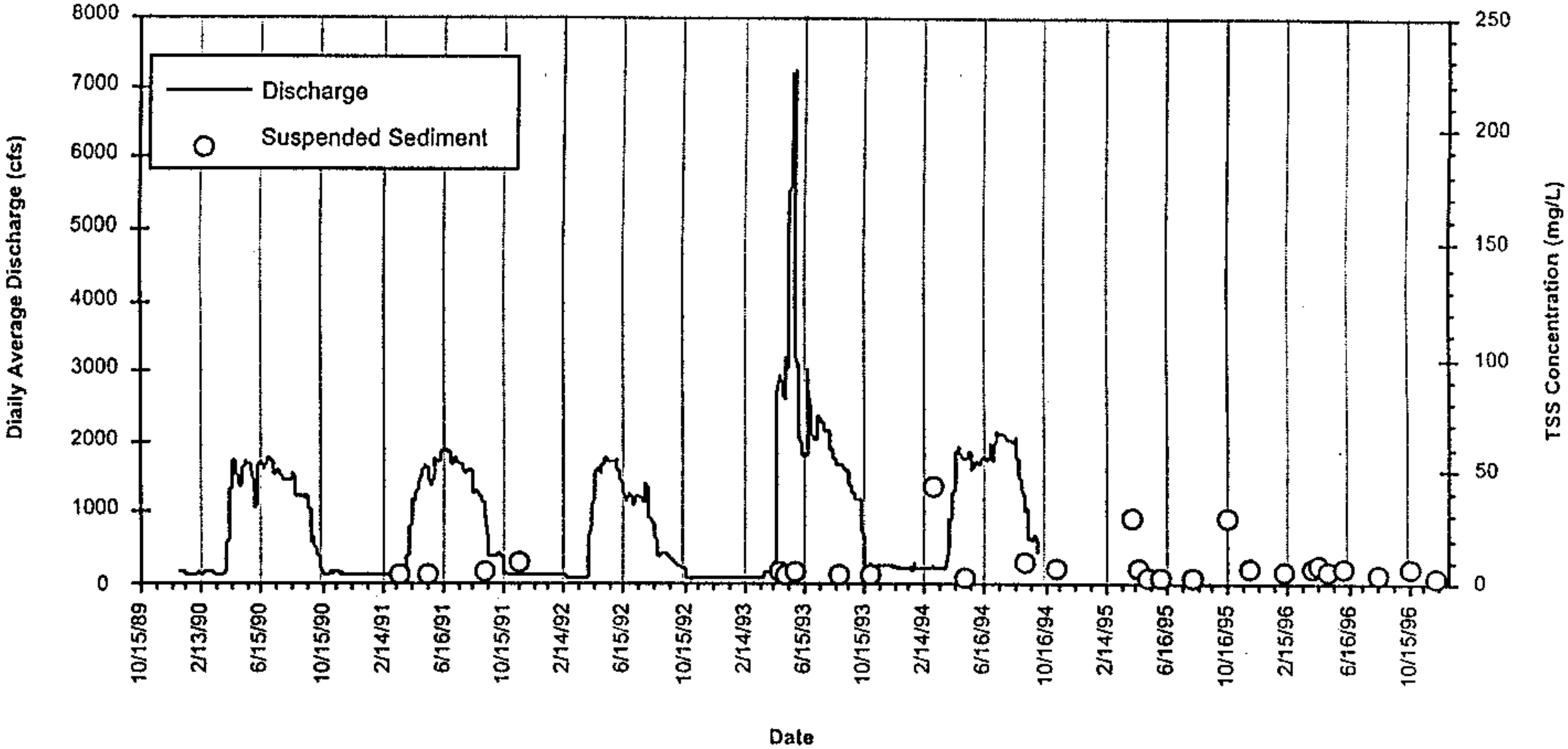


FIGURE 22
Boise River Below Diversion Dam–Daily Average Discharge Hydrograph and Instantaneous TSS Concentrations

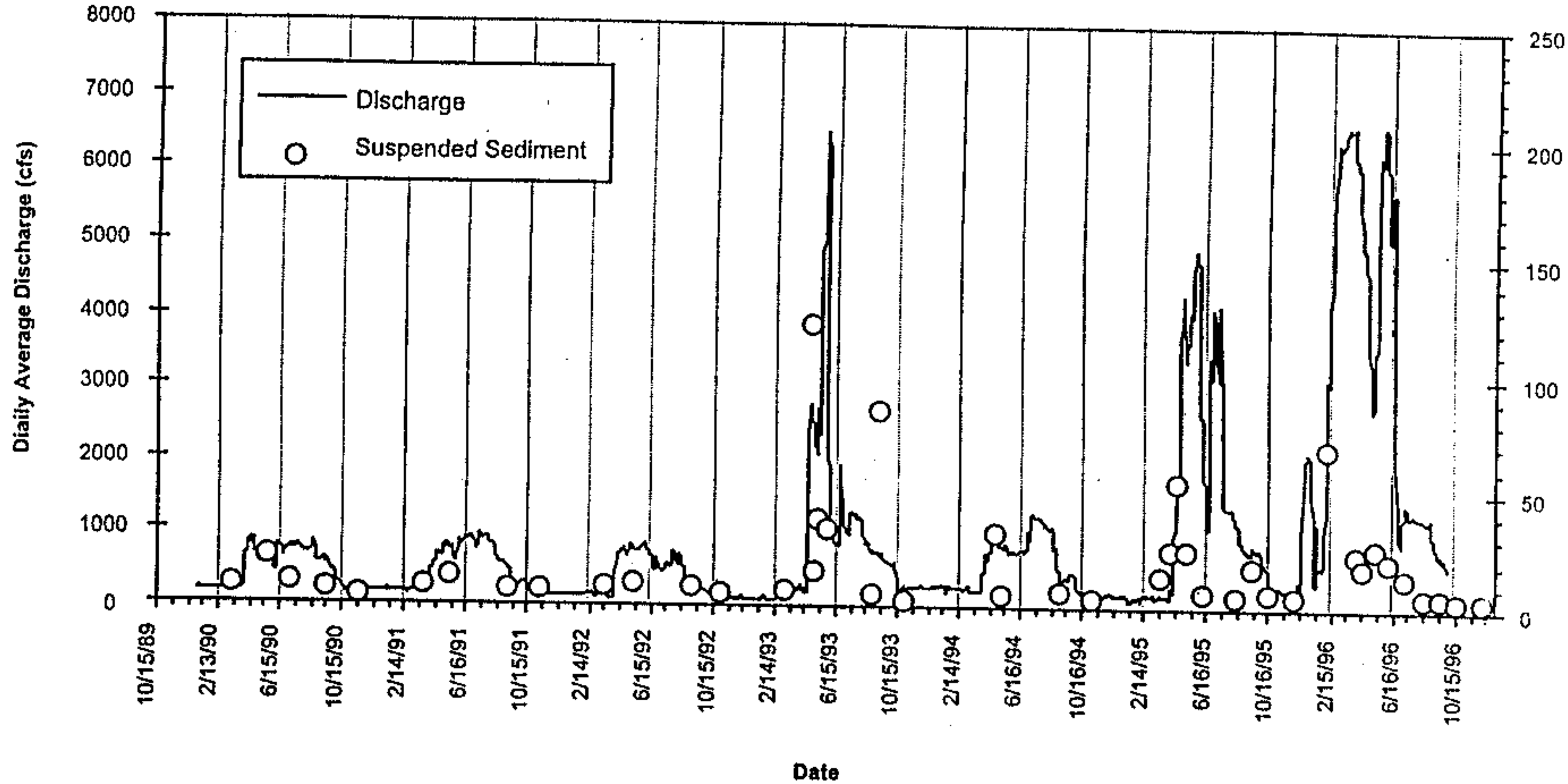


FIGURE 23
Boise River at Glenwood Bridge–Daily Average Discharge Hydrograph and Instantaneous TSS Concentrations

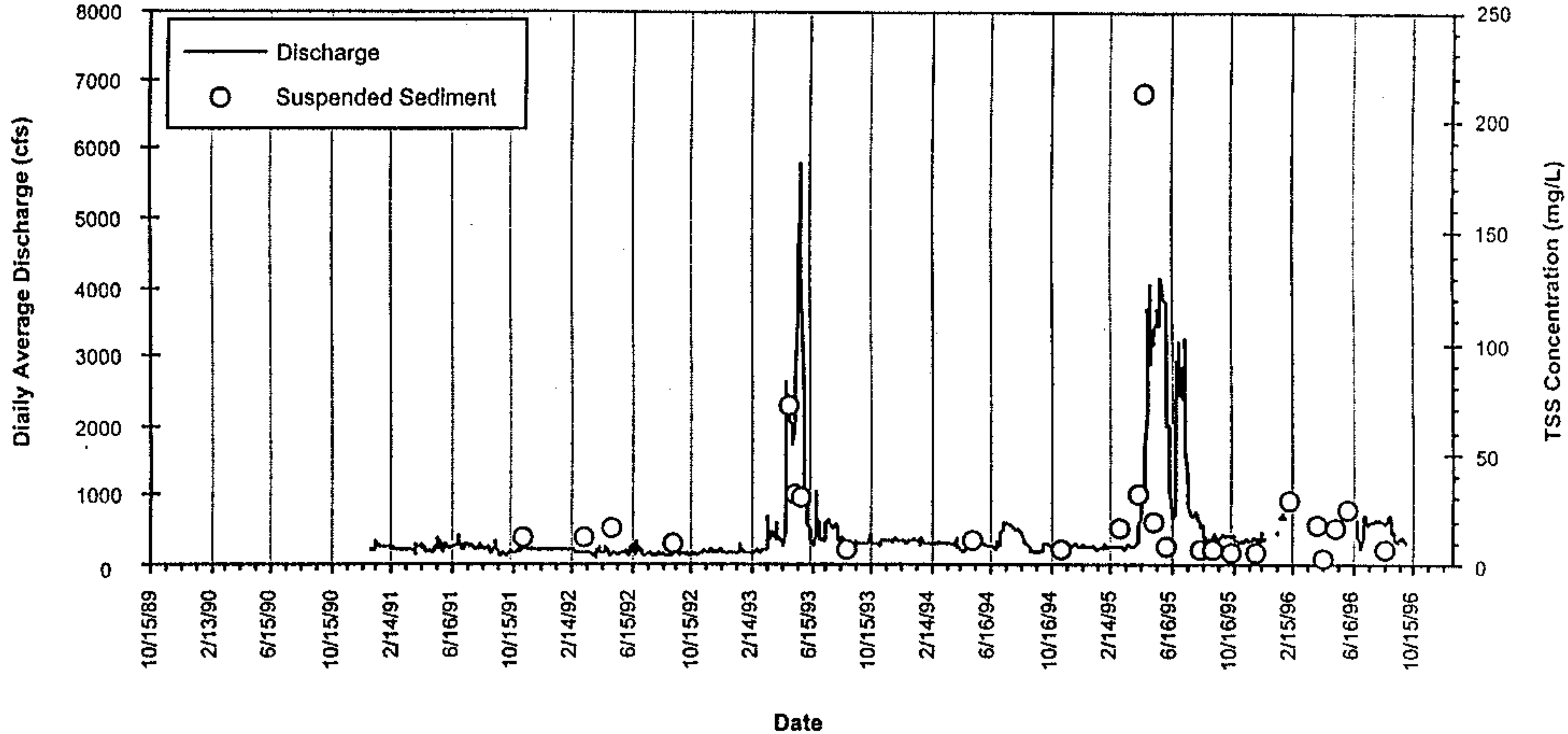


FIGURE 24
Boise River at Middleton–Daily Average Discharge Hydrograph and Instantaneous TSS Concentrations

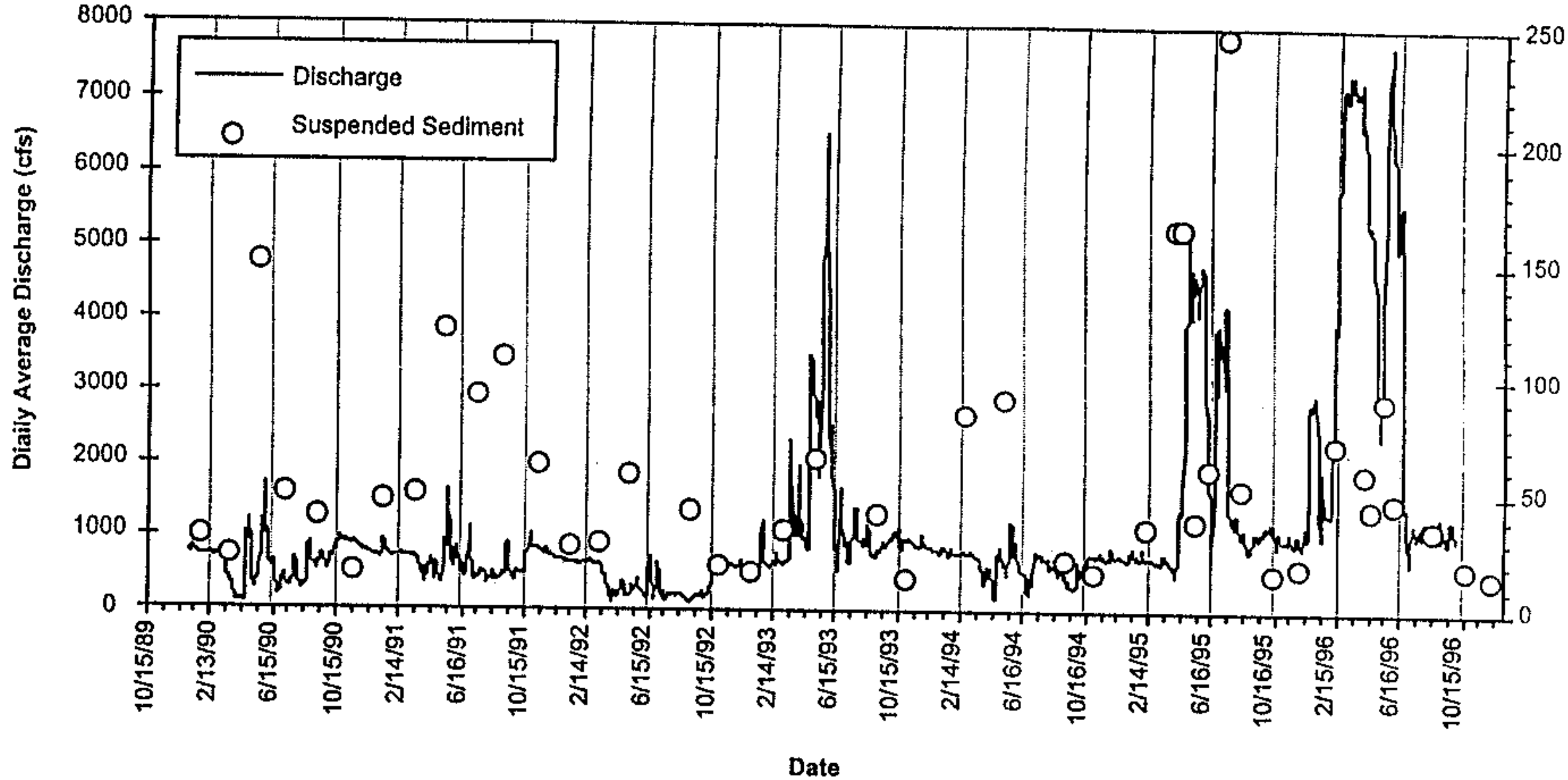
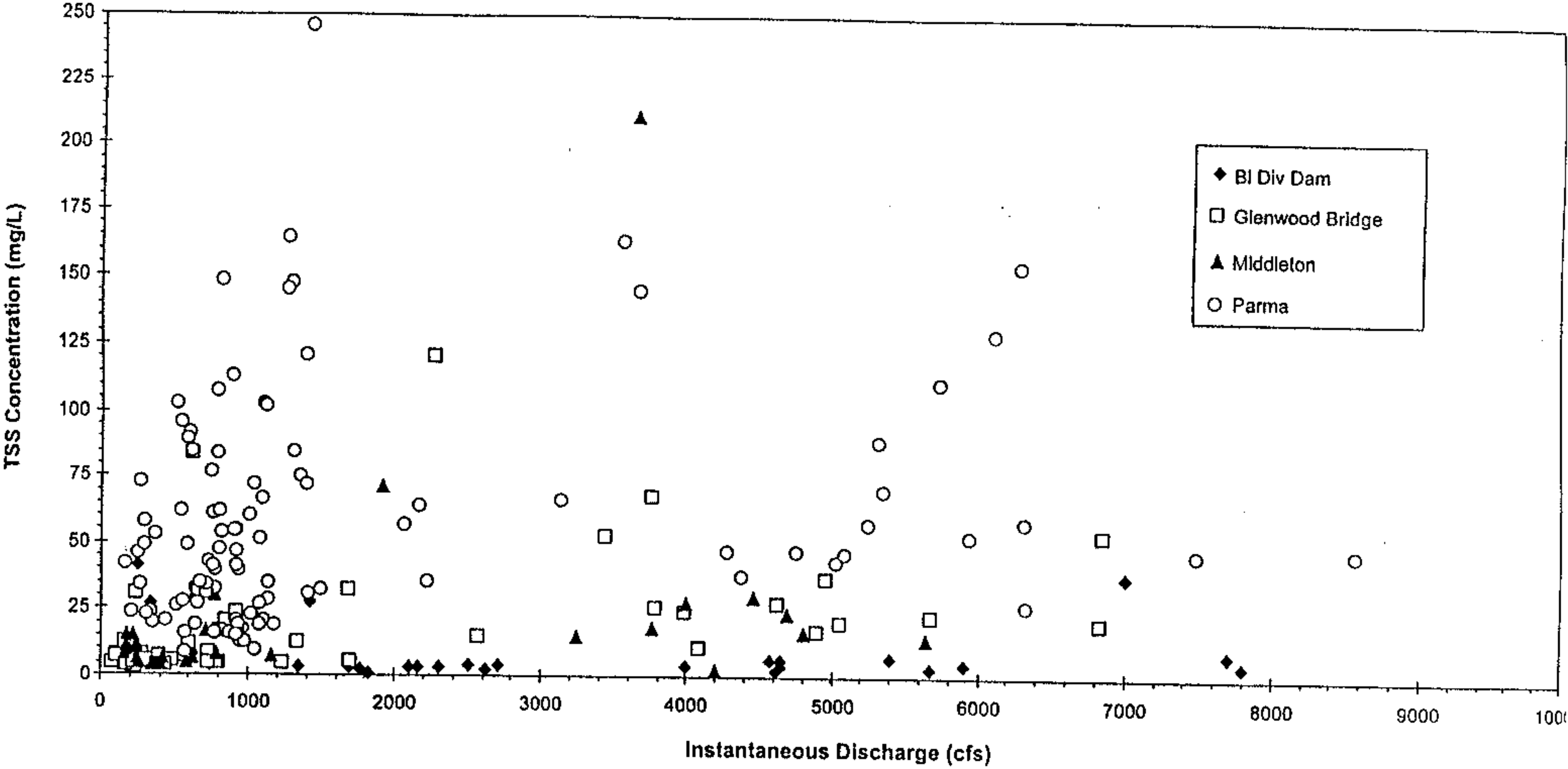


FIGURE 25
Boise River at Parma--Daily Average Discharge Hydrograph and Instantaneous TSS Concentrations



NOTE:
3 data points for Parma are offscale:

Q (cfs)	TSS (mg/L)	Date
1,830	664	12/74
1,670	483	8/75
3,490	467	1/76

FIGURE 26
Lower Boise River TSS Concentration Versus Instantaneous Discharge

Summary of Extent to Which Beneficial Uses are Impaired

Cold Water Biota

Based on the recommended acute and chronic TSS concentration limits for the protection of fish and their habitat, and based on the seasonal (121 day) TSS geometric mean concentrations in the main stem river and tributaries, the cold water biota use is likely being impaired from downstream of Middleton to the mouth of the river during the high- and irrigation-flow seasons. The word "likely" is used only because continuous (or more frequent) TSS data are unavailable to confirm the durations for which TSS concentrations exceed the 50 mg/L and 80 mg/L recommended TSS limits.

As seen in Figures 3 and 4, the TSS concentration limits are exceeded at Parma based on the geometric mean and 90th percentile concentrations during the high- and irrigation-flow seasons. Figure 25 provides a strong indication that the 50- and 80-mg/L recommended limits are exceeded for more than 60 and 14 days, respectively—thus impairing the cold water designated use.

Although the 90th percentile TSS concentration during the high-flow season at Middleton exceeds 50 mg/L (Figure 4), it seems unlikely that concentrations exceed 50 mg/L for more than 60 days or 80 mg/L for more than 14 days, based on Figure 24.

Salmonid Spawning

Salmonid spawning would be impaired under the same conditions described above. Therefore, salmonid spawning is being impaired from at least Middleton and downstream.

The limited available substrate data would also indicate that salmonid spawning is being impaired at locations near Middleton and the mouth of the Boise River. Although pebble count and percent embeddedness data are specific to a relatively small area at each sampling location, data from these locations are most likely indicative of the overall channel substrate condition between the two sites.

Major Sources

Waters (1995) reported that "among all sources of pollution afflicting streams and rivers, agriculture in its several forms is by far the most important—over three times the amount of pollution contributed by the next leading source (USEPA 1990)." In the lower Boise River watershed, probably the most significant source of sediment is agricultural lands. Among the various agricultural land use practices, the most significant source of sediment likely results from surface irrigated land. Unrestricted use of streamside areas by livestock, and the resulting trampling of streambanks, is another likely major source of sediment. The three tributaries with the highest seasonal loads of sediment in the lower Boise River watershed have drainage areas composed predominantly of agricultural lands.

Morris and Fan (1998) describe a cycle of sediment yield from urbanizing areas as the land use progresses from (1) low-yield predevelopment land uses, to (2) high-yield construction sites characterized by disturbed soil and a high-efficiency storm drainage network, to (3) protected soil cover. Urban areas in the lower Boise River watershed are a source of sediment; however, they are not likely a major source. This results from promotion of onsite stormwater retention and detention, and the relatively low annual rainfall in the valley, which provides little energy for sediment transport.

The watershed above Diversion Dam may represent a significant source of bed load sediment. However, because of a lack of bed load data from the vicinity of the Diversion Dam, the significance of this source remains unknown. The same is true for main stem streambank erosion; however, both of these sources are likely insignificant compared to the agricultural land areas.

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Appendix A

Selection of a Total Suspended Sediment (TSS) Target Concentration for the Lower Boise River TMDL

Selection of a Total Suspended Sediment (TSS) Target Concentration for the Lower Boise River TMDL

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DATE: March 13, 1998

Purpose

The purpose of this technical memorandum is to summarize the results, conclusions, and findings of published and unpublished studies pertaining to the effects of suspended sediment (SS) on selected species of fish and to select one or more appropriate target TSS concentration(s) to protect the existing and/or potential designated uses in the lower Boise River.

Literature Review

Background on Effects of Suspended Sediment

The effects of SS on fish vary with life stage (adult, juvenile, larvae, and eggs) and species (Sorensen et al. 1977; Waters 1995; Newcombe and Jensen 1996; Anderson et al. 1996; Sweeten 1998), as well as concentration of SS, duration of exposure, and particle size and angularity (Waters 1995; Anderson et al. 1996; Newcombe and Jensen 1996). Waters (1995) reported that salmonids have received the greatest attention regarding the effects of sediment on fish. This may be due to a number of reasons, including the great economic interest in the salmonids (Waters 1995) as well as their role as an indicator organism for cold water biota (e.g., Harvey 1989).

In a 1991 report, Newcombe and McDonald indicated that although the effects of SS on fish and aquatic life have been studied intensively, general principles characterizing environmental effects of suspended sediments had not been established. They noted that most published studies had only reported concentration; however, they stressed that the severity of effects is also related to duration of exposure. In exploring the relationship between SS concentration and duration in influencing changes in fish habitat in Canada, Anderson et al. (1996) found duration of exposure played a more dominant role than concentration.

In addition to habitat effects, a variety of effects associated with SS and fish are published in the literature. In general, these include lethal and sublethal effects. Waters (1995) provided discussions involving direct mortality and sublethal effects that included avoidance and distribution, reduced feeding and growth, respiratory impairment, reduced tolerance to disease and toxicants, and physiological stress. Anderson et al. (1996) summarized behavioral, physiological, and population effects, including avoidance of sediment plumes; reduction in feeding; loss of territoriality and interruption of migrational movements of salmonids; impaired growth rate; alteration in blood chemistry; gill trauma; resistance to disease and chemical toxins; phagocytosis (impairment of fish health because of envelopment of fine particles by cells within fish gill and gut tissue, which are then transported to internal repository tissues); egg mortality; and juvenile and adult fish mortality.

Newcombe and Jensen (1996) scored qualitative response data along a semiquantitative ranking (Table 1) to study the effect of sediment doses (concentration times exposure duration) on a variety of fish communities. The severity-of-ill-effect scale was ranked from 0 to 14 and included a variety of responses associated with excess SS. Superimposed on the 15-point scale were four major classes of effect: nil effect, behavioral effects, sublethal effects, and lethal effects. It was found that pollution episodes associated with sublethal or lethal effects also degraded habitat and reduced population size; therefore, these ill effects were grouped together in the hierarchy.

TABLE 1
Scale of the Severity (SEV) of Ill Effects Associated with Excess Suspended Sediment

SEV	Description of Effect
Nil Effect	
0	No behavioral effects
Behavioral Effects	
1	Alarm reaction
2	Abandonment of cover
3	Avoidance response
Sublethal Effects	
4	Short-term reduction in feeding rates
	Short-term reduction in feeding success
5	Minor physiological stress
	Increase in rate of coughing
	Increased respiration rate
6	Moderate physiological stress
7	Moderate habitat degradation
	Impaired homing
8	Indications of major physiological stress
	Long-term reduction in feeding rate
	Long-term reduction in feeding success
	Poor condition
Lethal and Paralethal Effects	
9	Reduced growth rate
	Delayed hatching
	Reduced fish density
10	0-20% mortality;
	Increased predation
	Moderate to severe habitat degradation
11	>20-40% mortality
12	>40-60% mortality
13	>60-80% mortality
14	>80-100% mortality

Source: Newcombe and Jensen (1996).

Because the issue of sediment effects on fish versus effects on habitat is an important issue, excerpts from Newcombe and Jensen's (1996) discussion of habitat damage associated with SS dose follows:

> Along the SEV scale, habitat damage ranges from moderate to severe. Habitat damage can be characterized in biological or physical terms or both of these in conjunction. Biological manifestations of habitat damage include underutilization of stream habitat (Birtwell et al. 1984), abandonment of traditional spawning habitat (Hamilton 1961), displacement of fish from their habitat (McLeay et al. 1987), and avoidance of habitat (Swenson 1978). Physical manifestations include degradation of spawning habitat (Slaney et al. 1977; Cederholm et al. 1981), damage to habitat structure (Newcomb and Flagg 1983; Menzel et al. 1984), and loss of habitat (Menzel et al. 1984; Coats et al. 1985). Biophysical manifestations of excess suspended sediment are reported (in one typical example) as habitat degradation that reduces the relative success of one or more fish species that depend on low siltation rates and silt-free (< 3% silt) riffles (Berkmann and Rabeni 1987) (p. 695).
>
> Habitat damage is a valid description of the harm caused by suspended sediment pollution, but it is probably an abstraction insofar as ill effects operate on one or more life stages of a fish's life cycle.... Habitat damage, therefore, should be seen as an accumulative measure of numerous (potentially undocumented) ill effects at various life stages in a fish's life cycle. It is a unique phenomenon in that it can only be studied in the field (in contrast to direct effects—age-specific morbidity and mortality, for example—that can be studied in the laboratory as well as in the field) (p. 695).

Existing or Suggested Mass-Based Suspended Sediment Criteria

The European Inland Fisheries Advisory Commission (EIFAC 1965) suggested the following standards for protection of salmonids and other fish:

<25 mg/L	No effect
25 - 80 mg/L	Slight effect on production
80 - 400 mg/L	Significant reduction in fisheries
>400 mg/L	Poor fisheries

Sorensen et al. (1977) reported that the Committee on Water Quality Criteria from the Environmental Studies Board of the National Academy of Sciences (CWQC 1973) relied heavily on the EIFAC study to recommend water quality criteria for the protection of aquatic communities. They reported the CWQC recommendation as follows:

Maximum Concentration of Suspended Solids	
25 mg/L	High level of protection
80 mg/L	Moderate protection
400 mg/L	Low level of protection
over 400 mg/L	Very low level of protection

In summarizing research needs related to standards on suspended and dissolved solids for protection of freshwater biota, Sorensen et al. (1977) wrote, "Standards which are similar to the recommended criteria of the CWQC (1973) are adequate for protecting fish against suspended solids" (p. 47).

The Water Quality Protection Section of the Alaska Department of Environmental Conservation (ADEC 1996) stated in a review, "It appears that only four states: Nevada, New Jersey, South Dakota, and West Virginia have numeric criteria for suspended solids in the water column" (p. 3-1). As reported in the review, they are as follows:

- Nevada employs specific limits for some stream reaches. The existing or higher quality is to be maintained whether the natural suspended solids concentration is equal to or less than 15 mg/L. The limit for the protection of all beneficial uses in the upper reaches of a watershed is 25 mg/L and 80 mg/L in the lower reaches.

- New Jersey limits suspended solids concentrations to 25 to 40 mg/L on specific streams.

- South Dakota has a 30 mg/L maximum limit for coldwater fisheries.

- West Virginia employs a 30 mg/L maximum suspended solids concentration in receiving waters.

They reported that 17 other states have general narrative statements addressing suspended and settleable solids.

The ADEC (1996) reported that there are no Canadian provinces or territories with water column standards for suspended and settleable solids. However, they list the following guideline established by Canada:

> Suspended solids should not exceed 10 $mg\text{-}L^{-1}$ when background suspended solids concentrations are equal to or less than 100 $mg\text{-}L^{-1}$. Suspended solids should not exceed 10% of background concentrations when background concentrations are greater than 100 $mg\text{-}L^{-1}$ (CCREM 1987).

Results from Suspended Sediment-Related Studies

Newcombe and Jensen (1996) conducted a meta-analysis of 80 published reports to develop matrices of SS concentration and duration of exposure (Figures 1 through 5) for quantifying the severity of ill effects (Table 1) on fish. Their analysis was based on 264 data triplets consisting of SS concentration, duration of exposure, and severity-of-ill effect for fishes. The data included taxonomic group, species of fish, natural history, life history phase, and sediment particle size range. Results of individual studies used in the meta-analysis pertaining to rainbow trout, brown trout, mountain whitefish, and a few from the adult nonsalmonids group are presented in Appendix A for review. Appendix B includes results of studies reviewed by Newcombe and MacDonald (1991) pertaining to aquatic invertebrates.

The matrices show empirical and modeled results for five groups of fish—juvenile and adult salmonids; adult salmonids; juvenile salmonids; eggs and larvae of salmonids and nonsalmonids; and adult freshwater nonsalmonids. The assumption for modeling purposes

Figure 1. Matrices Applicable to Juvenile and Adult Salmonids (from Newcombe and Jensen, [1996])

Duration of exposure to SS ($\log_e$ hours)

(A) Average severity-of-ill-effect scores (empirical)

Concentration (mg SS/L)	0	1	2	3	4	5	6	7	8	9	10	($\log_e$ mg SS/L)
162755	14	-	-	14	-	-	-	-	-	-	-	12
59874	-	-	12	10	14	12	-	-	-	-	-	11
22026	-	-	-	-	-	11	-	-	-	-	-	10
8103	3	-	-	10	12	10	-	11	-	14	-	9
2981	6	-	-	9	11	8	9	13	-	-	-	8
1097	4	-	-	-	10	9	11	8	-	14	8	7
403	4	5	8	-	-	8	10	9	10	-	-	6
148	4	-	6	9	-	8	9	9	-	-	-	5
55	2	4	5	-	-	7	10	9	10	-	-	4
20	3	4	-	4	-	-	-	10	-	9	-	3
7	-	-	-	-	-	3	-	9	-	9	-	2
3	-	-	-	-	-	5	-	-	-	-	-	1
1	3	-	-	-	-	-	-	-	-	-	-	0
	1	3	7	1	2	6	2	7	4	11	30	
	Hours			Days			Weeks		Months			

Duration of exposure to SS ($\log_e$ hours)

(B) Average severity-of-ill-effect scores (calculated)

Concentration (mg SS/L)	0	1	2	3	4	5	6	7	8	9	10	($\log_e$ mg SS/L)
162755	10	11	11	12	12	13	14	14	-	-	-	12
59874	9	10	10	11	12	12	13	13	14	-	-	11
22026	8	9	10	10	11	11	12	13	13	14	-	10
8103	8	8	9	10	10	11	11	12	13	13	14	9
2981	7	8	8	9	9	10	11	11	12	12	13	8
1097	6	7	7	8	9	9	10	10	11	12	12	7
403	5	6	7	7	8	9	9	10	10	11	12	6
148	5	5	6	7	7	8	8	9	10	10	11	5
55	4	5	5	6	6	7	8	8	9	9	10	4
20	3	4	4	5	6	6	7	8	8	9	9	3
7	3	3	4	4	5	6	6	7	7	8	9	2
3	2	2	3	4	4	5	5	6	7	7	8	1
1	1	2	2	3	3	4	5	5	6	7	7	0
	1	3	7	1	2	6	2	7	4	11	30	
	Hours			Days			Weeks		Months			

Figures 1 through 5: (A) Average empirical severity-of-ill-effect scores for juvenile and adult salmonids (freshwater, group 1) in the matrix of suspended sediment (SS) concentration and duration of exposure. Both matrix axes are expressed in logarithmic and absolute terms. Dashes mean "no data." Shaded bands denote inferred (by manual interpolation) thresholds of sublethal effects (shading without a border) and lethal effects (shading with a border; see Table 1 for criteria.). Severity-of-ill-effect scores calculated by model (1) (Table 2). Severity-of-ill-effect calculations are based on the logarithmic values shown on the axes of the matrix. Shaded areas represent extrapolations beyond empirical data; extrapolations have been capped at 14 (upper limit of the effects scale: Table 1), although higher values are possible. Diagonal terraced lines denote thresholds of sublethal effects (lower left) and lethal effects (middle diagonal) delineated by the model with reference to Table 1.

Figure 2. Matrices Applicable to Adult Salmonids (from Newcombe and Jensen [1996])

Duration of exposure to SS (log_e hours)

(A) Average severity-of-ill-effect scores (empirical)

Concentration (mg SS/L)	0	1	2	3	4	5	6	7	8	9	10	(log_e mg SS/L)
162755	14	-	-	14	-	-	-	-	-	-	-	12
59874	-	-	12	10	-	12	-	-	-	-	-	11
22026	-	-	-	-	-	10	-	-	-	-	-	10
8103	-	-	-	10	-	-	-	-	-	14	-	9
2981	-	-	-	10	-	-	12	13	-	-	-	8
1097	-	-	-	-	-	7	9	-	-	14	8	7
403	5	5	8	-	-	7	9	12	10	-	-	6
148	4	-	-	10	-	-	-	9	-	-	-	5
55	3	4	-	-	-	7	-	9	10	-	-	4
20	-	4	-	4	-	-	-	10	-	-	-	3
7	-	-	-	-	-	3	-	-	-	-	-	2
3	-	-	-	-	-	5	-	-	-	-	-	1
1	3	-	-	-	-	-	-	-	-	-	-	0
	1	3	7	1	2	6	2	7	4	11	30	
	Hours			Days			Weeks		Months			

Duration of exposure to SS (log_e hours)

(B) Average severity-of-ill-effect scores (calculated)

Concentration (mg SS/L)	0	1	2	3	4	5	6	7	8	9	10	(log_e mg SS/L)
162755	11	11	12	12	13	13	14	14	-	-	-	12
59874	10	10	11	11	12	12	13	13	14	14	-	11
22026	9	10	10	11	11	12	12	13	13	14	14	10
8103	8	9	9	10	10	11	11	12	12	13	13	9
2981	8	8	9	9	10	10	11	11	12	12	13	8
1097	7	7	8	8	9	9	10	10	11	11	12	7
403	6	7	7	8	8	9	9	10	10	11	11	6
148	5	6	6	7	7	8	8	9	9	10	10	5
55	5	5	6	6	7	7	8	8	9	9	9	4
20	4	4	5	5	6	6	7	7	8	8	9	3
7	3	4	4	5	5	6	6	7	7	7	8	2
3	2	3	3	4	4	5	5	6	6	7	7	1
1	2	2	3	3	4	4	5	5	5	6	6	0
	1	3	7	1	2	6	2	7	4	11	30	
	Hours			Days			Weeks		Months			

Figure 3. Matrices Applicable to Juvenile Salmonids (from Newcombe and Jensen [1996])

Duration of exposure to SS ($\log_e$ hours)

(A) Average severity-of-ill-effect scores (empirical)

Concentration (mg SS/L)	Hours 1	Hours 3	Hours 7	Days 1	Days 2	Days 6	Weeks 2	Weeks 7	Months 4	Months 11	Months 30	($\log_e$ mg SS/L)
Duration ($\log_e$ hours)	0	1	2	3	4	5	6	7	8	9	10	
162755	-	-	-	-	-	-	-	-	-	-	-	12
59874	-	-	-	-	14	12	-	-	-	-	-	11
22026	-	-	-	-	-	11	-	-	-	-	-	10
8103	3	-	-	-	12	10	-	11	-	-	-	9
2981	6	-	-	8	11	8	8	13	-	-	-	8
1097	4	-	-	-	10	10	12	8	-	-	-	7
403	4	-	-	-	-	10	12	9	-	-	-	6
148	4	-	6	6	-	8	9	9	-	-	-	5
55	2	-	5	-	-	-	10	-	9	-	-	4
20	3	-	-	3	-	-	-	-	-	9	-	3
7	-	-	-	-	-	-	-	9	-	9	-	2
3	-	-	-	-	-	-	-	-	-	-	-	1
1	-	-	-	-	-	-	-	-	-	-	-	0

Duration of exposure to SS ($\log_e$ hours)

(B) Average severity-of-ill-effect scores (calculated)

Concentration (mg SS/L)	Hours 1	Hours 3	Hours 7	Days 1	Days 2	Days 6	Weeks 2	Weeks 7	Months 4	Months 11	Months 30	($\log_e$ mg SS/L)
Duration ($\log_e$ hours)	0	1	2	3	4	5	6	7	8	9	10	
162755	9	10	11	11	12	13	14	14	-	-	-	12
59874	9	9	10	11	11	12	13	14	14	-	-	11
22026	8	9	9	10	11	11	12	13	13	14	-	10
8103	7	8	9	9	10	11	11	12	13	13	14	9
2981	6	7	8	9	9	10	11	11	12	13	13	8
1097	6	6	7	8	9	9	10	11	11	12	13	7
403	5	6	6	7	8	9	9	10	11	11	12	6
148	4	5	6	6	7	8	9	9	10	11	11	5
55	4	4	5	6	6	7	8	8	9	10	11	4
20	3	4	4	5	6	6	7	8	8	9	10	3
7	2	3	4	4	5	6	6	7	8	8	9	2
3	1	2	3	4	4	5	6	6	7	8	8	1
1	1	1	2	3	4	4	5	6	6	7	8	0

Figure 4. Matrices Applicable to Eggs and Larvae Salmonids and Nonsalmonids (from Newcombe and Jensen [1996])

Duration of exposure to SS ($\log_e$ hours)

(A) Average severity-of-ill-effect scores (empirical)

Concentration (mg SS/L)	1 Hours (0)	3 Hours (1)	7 Hours (2)	1 Days (3)	2 Days (4)	6 Days (5)	2 Weeks (6)	7 Weeks (7)	4 Months (8)	11 Months (9)	30 Months (10)	($\log_e$ mg SS/L)
162755	-	-	-	-	-	-	-	-	-	-	-	12
59874	-	-	-	-	-	-	-	-	-	-	-	11
22026	-	-	-	-	-	-	-	-	-	-	-	10
8103	-	-	-	-	-	-	-	-	-	-	-	9
2981	-	4	-	8	-	-	-	-	-	-	-	8
1097	-	-	-	9	11	10	-	-	-	-	-	7
403	-	-	-	12	12	11	-	-	-	-	-	6
148	4	-	-	9	12	11	13	12	13	-	-	5
55	-	-	-	10	-	-	-	13	-	-	-	4
20	-	-	-	7	10	10	-	13	-	-	-	3
7	-	3	-	-	-	-	-	11	-	-	-	2
3	-	-	-	-	-	-	-	-	-	-	-	1
1	-	-	-	-	-	-	-	-	-	-	-	0

Duration of exposure to SS ($\log_e$ hours)

(B) Average severity-of-ill-effect scores (calculated)

Concentration (mg SS/L)	1 Hours (0)	3 Hours (1)	7 Hours (2)	1 Days (3)	2 Days (4)	6 Days (5)	2 Weeks (6)	7 Weeks (7)	4 Months (8)	11 Months (9)	30 Months (10)	($\log_e$ mg SS/L)
162755	7	9	10	11	12	13	14	-	-	-	-	12
59874	7	8	9	10	12	13	14	-	-	-	-	11
22026	7	8	9	10	11	12	13	-	-	-	-	10
8103	7	8	9	10	11	12	13	14	-	-	-	9
2981	6	7	8	10	11	12	13	14	-	-	-	8
1097	6	7	8	9	10	11	12	14	-	-	-	7
403	6	7	8	9	10	11	12	13	14	-	-	6
148	5	6	7	9	10	11	12	13	14	-	-	5
55	5	6	7	8	9	10	12	13	14	-	-	4
20	5	6	7	8	9	10	11	12	13	-	-	3
7	4	5	7	8	9	10	11	12	13	14	-	2
3	4	5	6	7	8	10	11	12	13	14	-	1
1	4	5	6	7	8	9	10	11	13	14	-	0

Figure 5. Matrices Applicable to Adult Freshwater Nonsalmonids (from Newcombe and Jensen [1996])

Duration of exposure to SS ($\log_e$ hours)

(A) Average severity-of-ill-effect scores (empirical)

Concentration (mg SS/L)	0	1	2	3	4	5	6	7	8	9	10	($\log_e$ mg SS/L)
162755	10	-	-	-	-	-	10	-	-	-	-	12
59874	-	-	-	-	-	-	-	-	-	-	-	11
22026	-	-	-	-	-	-	10	-	-	-	-	10
8103	5	-	-	-	-	-	-	-	-	-	-	9
2981	-	-	-	-	-	-	-	-	-	13	-	8
1097	-	-	-	-	-	-	-	12	-	-	-	7
403	4	-	-	-	10	-	-	-	-	-	-	6
148	-	-	-	-	-	-	10	11	-	-	-	5
55	-	-	-	-	-	-	-	9	-	-	-	4
20	4	-	-	-	-	-	-	-	-	12	-	3
7	-	-	-	-	-	-	-	-	-	-	-	2
3	-	-	-	-	-	-	-	-	-	-	-	1
1	-	-	-	-	-	-	-	-	-	-	-	0
	1	3	7	1	2	6	2	7	4	11	30	
	Hours			Days			Weeks		Months			

Duration of exposure to SS ($\log_e$ hours)

(B) Average severity-of-ill-effect scores (calculated)

Concentration (mg SS/L)	0	1	2	3	4	5	6	7	8	9	10	($\log_e$ mg SS/L)
162755	7	8	9	10	10	11	12	12	13	14	[illegible]	12
59874	7	8	9	9	10	11	11	12	13	14	14	11
22026	7	8	8	9	10	10	11	12	13	13	14	10
8103	7	7	8	9	9	10	11	12	12	13	14	9
2981	6	7	8	8	9	10	11	11	12	13	13	8
1097	6	7	7	8	9	10	10	11	12	12	13	7
403	6	6	7	8	9	9	10	11	11	12	13	6
148	5	6	7	8	8	9	10	10	11	12	13	5
55	5	6	7	7	8	9	9	10	11	12	12	4
20	5	6	6	7	8	8	9	10	11	11	12	3
7	5	5	6	7	7	8	9	10	10	11	12	2
3	4	5	6	7	7	8	9	9	10	11	11	1
1	4	5	6	6	7	8	8	9	10	10	11	0
	1	3	7	1	2	6	2	7	4	11	30	
	Hours			Days			Weeks		Months			

was that the severity-of-ill-effects scale (Table 1) represented proportional differences in true effects. The attributes, slopes and coefficients, and statistics of the regression models developed for the five different data groupings are shown in Table 2. As pointed out by Anderson et al. (1996), the multiple regression approach used by Newcombe and Jensen (1996) allowed for different factors (slopes) to be assigned separately to the variables of concentration and duration, which is important to address the potential for non-linearity in the relationship between the two variables.

TABLE 2
Attributes, Slopes, and Coefficients, and Statistics of Six Models that Relate Severity of Ill Effects on Fishes (z, 15-Point Scale) to Duration of Exposure (x, h) and Concentration of Suspended Sediment (y, mg/L) in the Form $z = a + b(\log_e x) + c(\log_e y)$.

Term	Model 1	Model 2	Model 3	Model 4	Model 6
Attributes					
Taxon[a]	S	S	S	S + N	N
Life Stage[b]	J + A	A	J	E + L	A
Life History[c]	FW	FW	FW	FW + ES	FW
Sediment Particle Size[d]	F to C	F to C	F	F	F
Slopes and Coefficients					
Intercept (a)	1.0642	1.6814	0.7262	3.7466	4.0815
Slope of $\log_e x$ (b)	0.6068	0.4769	0.7034	1.0946	0.7126
Slope of $\log_e y$ (c)	0.7384	0.7565	0.7144	0.3117	0.2829
Statistics					
Coefficient of Determination[e] (r^2)	0.6009	0.6173	0.5984	0.5516	0.6998
F-statistic	130.28	52.37	82.00	28.03	27.42
Probability (P)	<0.01	<0.01	<0.01	<0.01	<0.01
Sample Size (N)	171	63	108	43	22

[a] S = Salmonids (predominantly); N = nonsalmonids.
[b] A = Adults; J = juveniles; L = larvae; E = eggs.
[c] FW = Freshwater and anadromous; ES = estuarine.
[d] F = Fine (predominately <75 µm); C = coarse (75-250 µm).
[e] Corrected for degrees of freedom.

Source: Newcombe and Jensen (1996).

Buck (1956) showed that "turbidity," expressed as parts per million, had a marked influence on the production of largemouth bass, bluegills, and redear sunfish (warm water fish). The researcher artificially created turbidities in a total of 12 ponds: In 6 ponds, sodium silicate (a relatively inert substance used to keep the clay in suspension) was mixed with native clay and in the remaining 6 ponds, adult carp were added. The ponds were classified as 1) clear ponds—average turbidities <25 ppm; 2) intermediate ponds—turbidity range of 25 to 100 ppm; and 3) muddy ponds—turbidity >100 ppm. Relative to the clear ponds, the intermediate and muddy ponds exhibited lower total weight of fish, slower growth rates, and reduced reproduction rate and success. Results from this study were included in Newcombe and Jensen's (1996) meta-analysis.

The U.S. Fish and Wildlife Service habitat suitability index model for largemouth bass (Stuber et al. 1982) reports the optimum suspended solids concentration for largemouth bass ranges from 5-25 mg/L.

Sweeten (1998) used bentonite clay suspensions (particle size 0.0010-0.0005 mm) in recirculating tanks to quantify the effects of suspended solids on centrarchids and other sight feeding fishes. He proposes that the methodology, similar to those used to regulate toxic substances, is suitable for developing numerical criteria for suspended solids; however, to date, his results have not been field validated. A summary of the results follow:

- The clay concentration causing a 25 percent reduction in total biomass (IC25) after 7 days for juvenile smallmouth bass was 35 mg/L.
- For juvenile bluegill, the IC25 after 14 days was 76 mg/L.
- Survival rates for larval smallmouth bass and bluegill were less than 50 percent at the concentrations listed above.

Reporting that a number of SS criteria have been based on observations of fish populations under chronic exposure, Anderson et al. (1996) extended the work of Newcombe and others and used a multiple regression analysis to develop an acute sediment dose/habitat effect relationship. The following relationship was significant ($P<0.001$); however, they had not yet field tested it:

$$z = 0.637 + 0.740\ \mathrm{Ln(SS\ Concentration)} + 0.864\ \mathrm{Ln(Duration)};\ r^2(\mathrm{adj})=0.627;\ n=35;\ p<0.001.$$

where z = severity-of-ill-effect—either 3, 7, 10, 12, or 14 based on a ranking system that followed the one used by Newcombe and Jensen (1996) shown in Table 1.

Peters (1967) studied the effects of sediment from agricultural practices on Bluewater Creek, a trout stream in Montana. The description of the study stream and watershed shares similarities to the lower Boise River system. Excerpts of the author's description follow:

- The study area is subject to low annual precipitation (about 11 inches per year, over three-fourths of which occurs in the winter).
- Irrigation diversions occur from April to October.
- During the irrigation season, the return surface flow changes the quality, quantity, and temperature of the water in the lower 9 miles of the 15-mile stream.
- Except for infrequent runoff in the watershed, caused by rain showers or rapid melting of snowpack, the creek could be characterized as one with an extremely stable year-round flow (except in the lower 9 miles during irrigation season).
- The most populous salmonid is introduced brown trout.
- Other species of fish (classified as rough fish by the author) include flathead chub, longnose dace, white sucker, longnose sucker, and mountain sucker.

The range of suspended sediment concentrations in Bluewater Creek (see Appendix C) are similar to those measured in the lower Boise River system. Like the lower Boise River, Bluewater Creek exhibited a trend of increasing sedimentation in the downstream direction—a trend the author attributed to the predominant agricultural land use in the lower reach of the creek.

The average monthly suspended sediment data measured approximately twice weekly at five stations during the 2-year study are presented in Appendix C. The median values for these monthly concentrations were: Station I—18 ppm; II—79 ppm; III—167 ppm; IV—186 ppm; and V—319 ppm. The stations were spaced approximately 3 miles apart; Station I denoted the upstream station, V the most downstream.

Results of the study showed that trout of all ages were abundant where sediment concentrations or loads were low (range in daily load 0.2 to 11 tons); few were found where sediment concentrations or loads were high (range in daily load 2 to 1,800 tons). Brown trout were "abundant" in the vicinity of Stations I and II; "marginal" near III; and, "incidental" at IV and V. The total number of trout estimated (using mark-and-recapture electrofishing surveys) at Station I was 1.4 times higher than Station II, 2.6 times higher than III, 33.3 times higher than IV, and 44.3 times higher than V (Table C-4).

Another significant finding of the study was the difference in age composition of trout at the different stations. In the vicinity of Stations I and II, the age composition was as follows: Age group, 0-I—42 percent; I-II—30 percent; II-III—14 percent; III-IV—9 percent; and IV and older—5 percent. Only 6 percent of the total number of trout censused in the area of Station III were in the 0-I age group. Downstream of Station III, there were no trout from age-class I or II. (Age-0 group are fish in their first year of life, before their first January 1 birth date; and a fish in age group I has completed 1 year or less of growth from time of hatching to the January 1 birth date and has entered its second growth season [Nielsen and Johnson 1989].)

See Appendix C for the monthly average SS concentrations, monthly mean maximum and minimum temperature, and electrofishing results. Also included in Appendix C is a table of the mortality rates of eyed-rainbow trout eggs incubated in man-made redds at each station. Results from this study were used in Newcombe and Jensen's (1996) meta-analysis.

Bases for the Determination of a Target TSS Concentration for the Lower Boise River

EIFAC (1965) and CWQC (1973) Studies

Based on the EIFAC (1965) suggested standards, an appropriate target concentration for protecting fish from excessive suspended sediment might be anywhere from 25 to 80 mg/L. The associated effect at this range of concentration is described as a "slight effect on production."

Although the original EIFAC report was not reviewed for the development of this memo, a summary table of the data used in the original EIFAC review was presented by Sorenson et al. (1977) and reviewed for this memo. No durations were listed with the EIFAC's suggested concentration ranges; however, it appears that duration was accounted for in terms of when a given effect occurred (for example, 20 percent mortality in 2 to 6 weeks at

90 ppm). In addition, based on the table presented in Sorenson et al. (1977), studies pertaining to various life stages were reviewed by the EIFAC.

Regarding the EIFAC suggested standards, it is important to note that 80 mg/L was the upper limit associated with a "slight effect on production" and the lower limit associated with a "significant reduction in fisheries." Recall also that the CWQC (1973) recommended 80 mg/L as the *maximum* concentration of suspended solids for *moderate* protection of aquatic communities. Based on these two recommendations, 80 mg/L would be considered the maximum concentration not to be exceeded for protection of the aquatic community.

Existing State TSS Water Quality Standards

In comparison to the two studies discussed above, the existing TSS standards for South Dakota, New Jersey, and West Virginia are at the low, or more protective end of the suggested concentration ranges. Nevada's TSS standard spans the 25 to 80 mg/L range with 25 mg/L being applicable to the upper reaches of the watershed and 80 mg/L to the lower.

Individual Studies Used in Newcombe and Jensen's (1996) Quantitative Assessment

From the 80 studies included in Newcombe and Jensen's (1996) meta-analysis, there were 14 data triplets (concentration, duration, and effect) with TSS concentrations ≤80 mg/L that pertain specifically to some of the fish species present in the lower Boise River (see Appendix A). Of the 14 data triplets, the durations ranged from 1 to 365 days. Thirteen of these resulted in sublethal, or lethal and paralethal effects, as defined by the authors. The minimum duration associated with the 13 data triplets was 30 days. Six of the 13 data sets described effects associated with forest harvesting practices; three involved agricultural practices; one involved artificially induced turbidity and turbidity generated by other fish; one dealt with placer mining; and two dealt with sediment from an industrial origin.

Based on a strict interpretation of the data sets listed in Appendix A, if a target concentration were set at >50 mg/L but ≤80 mg/L, three data sets (shaded in Appendix A) suggest that if concentrations in this range were sustained for 30 or more days, lethal or paralethal effects may occur. Two data sets (shaded) suggest sublethal and behavioral effects might occur at durations ≤7 days. Similarly, three data sets (shaded) in Appendix B suggest the potential for significant reductions in invertebrate populations as well.

Using the same logic, if a target concentration were set at 50 mg/L, eight data sets in Appendix A (shown with bold borders) suggest that lethal or paralethal effects may occur at or below 50 mg/L if sustained for 30 or more days. One data set indicates sublethal effects may occur if 17 mg/L were sustained for only 1 day. Similarly, five (bold-bordered) data sets in Appendix B suggest the potential for a reduction in the invertebrate standing crop if concentrations as low as 8 mg/L or 10 mg/L were sustained for at least 60 or 30 days, respectively.

Matrices and Models Developed by Newcombe and Jensen (1996)

Benefits

The individual data sets in Appendices A and B provide insight as to the sensitivity—and ultrasensitivity in the case of the egg and larval stages—of fish. However, the study conditions associated with these relatively few data sets may not adequately represent the range of conditions that exist in the lower Boise River. Because Newcombe and Jensen (1996) synthesized 264 data sets from 80 studies to develop their matrices and models (Figures 1 through 5 and Table 2), their analysis included a broad range of conditions. Therefore, these matrices and models are very useful for selecting a target concentration that would be protective over a wide range of conditions.

This is important because the impacts on fish populations subjected to an event of high sediment concentrations may very depending on study conditions. For example, the effect of a given sediment dose on a fish population may be different if the population is confined to a laboratory flume with no refuge, compared to a wild population in a natural stream that may have the ability to move about the stream system. Confounding factors such as temperature of the receiving environment and particle size and shape add to the potential variation in effect that may be observed at a given sediment dose.

General Observations

For the matrices shown in Figures 1 through 4, the thresholds of lethal effects are typically more conservative from the empirical matrices than the calculated matrices; however, across the full range of TSS concentrations, the relationship is the reverse for the matrices applicable to the adult freshwater nonsalmonids group. Figure 4 reflects that the most sensitive life stages are the egg and larval stages—a finding consistently supported throughout the literature. A comparison of Figure 5 to Figures 1 and 2 indicates that the adult nonsalmonids seem to be more sensitive to sediment doses than the adult salmonids.

Validation

Before employing the matrices as a tool for selecting an appropriate target TSS limit, it is worth discussing validation of the models. The authors stated that validation would rely on new studies to add to the data available at that time; however, even prior to publishing, they were able to utilize new data that had emerged. They cited recent finding of four studies that tended to support the predictions of the models—one of which (Sweeten 1998) was presented earlier in this paper and involved the most sensitive life stage of fish. It is shown again here in relation to the appropriate model developed by Newcombe and Jensen (1996).

> At a concentration of 35 mg/L and a duration of 7 days, the calculated severity-of-ill-effect score computed from Model 4 (eggs and larvae of salmonids and nonsalmonids) is 10. From Table 1, the description of SEV = 10 is: 0 to 20 percent mortality; increased predation; and moderate to severe habitat degradation. Sweeten (1998) reported survival rates for larval smallmouth bass of less than 50 percent at this sediment dose under laboratory conditions. Thus, although the model actually underestimated the severity of ill effect, it was accurate in predicting exceedance of the lethal threshold (SEV$\geq$9).

At a concentration of 76 mg/L and a duration of 14 days, Model 4 results in a SEV = 11: >20 to 40 percent mortality (Table 1). Sweeten (1998) reported survival rates for larval bluegill of less than 50 percent at this sediment dose under laboratory conditions. Again, in this case, the model prediction was very close, only slightly underestimating the actual effect.

Selecting an Appropriate Duration for Protection Against Chronic Impacts

Choosing an appropriate duration for the selection of a target TSS concentration is critical because it is an important variable that influences the severity of ill effect on a fishery. This significance is not lost when employing the matrices and models developed by Newcombe and Jensen (1996). An example follows, using Model 2 (presented in matrix form in Figure 2), of a situation that must be avoided when employing the matrices and models. (Note that if Model 4 were used in the example, the threshold of lethal effects (SEV ≥ 9; see Table 1) would be exceeded at a much shorter duration:

> If the target TSS concentration not to be exceeded—based on a 10-day average or geometric mean—were 100 mg/L, then technically, 100 mg/L could be sustained for 365 days, year after year, and the target would never be exceeded. After 129 days, however, the threshold of lethal effects would be exceeded (SEV = 9, computed by Model 2). It could be argued that the selected target is not protective since lethal effects could occur, even within the limits of the target, after only approximately 4 months.

Because of this situation, it is appropriate to select a target TSS concentration that would be protective over a *duration equal to the maximum probable length of time for which an elevated TSS concentration would be sustained*. This approach would rely on the seasonal variation in flow regimes and land use practices to avoid having to select a duration that continues indefinitely, or even annually; yet, it would be protective for a duration equal to the maximum probable length of time for which elevated TSS concentrations would be sustained.

In the lower Boise River, this period of elevated TSS concentrations might be 121 days to equal the duration of the three predominant seasonal flow regimes (hereafter referred to as hydrologic seasons): High flow—February 15 to June 14; irrigation flow—June 15 to October 14; and low flow—October 15 to February 14. However, in the absence of TSS-duration data, and due to the TSS first-flush effect during the high-flow and irrigation-flow hydrologic seasons, *a protective, yet not overly conservative, duration would be 60 days*. This duration is one-half of each of the three hydrologic seasons and one-third of the agricultural diversion period (April 15 to October 15). Sustained elevated concentrations of TSS are not likely to occur during the low-flow season or for the entire duration of the high-flow and irrigation-flow hydrologic seasons.

Sublethal and Paralethal TSS Concentrations Associated with 60-Day Durations

Table 3 presents for a range of TSS concentrations the computed durations of exposure associated with an SEV=9—the minimum severity-of-ill-effect score in the lethal and paralethal category of Newcombe and Jensen's (1996) severity scale (Table 1). Thus, for the life stages and fish species represented by the models, the TSS concentrations associated with the shaded durations in Table 3 would not be protective against lethal and paralethal effects if sustained for up to 60 days. Similarly, based on the Anderson et al. (1996) fish

Table 3

Calculated Durations Associated with a Severity-of-Ill-Effect Score = 9 Based on Six Different Models[a]

TSS Concentration (mg/L)	Calculated Duration (days)					
	Acute Habitat Impact Model[b]	Model Number[c]				
		1[d]	2[e]	3[f]	4[g]	6[h]
1	666	19932	192556	5348	5	41
5	168	2812	14990	1043	3	22
10	93	1210	4992	516	3	17
15	65	739	2624	342	2	14
20	51	520	1662	255	2	13
25	42	397	1167	203	2	12
30	36	318	874	169	2	11
35	32	263	684	145	2	10
40	28	224	554	126	2	10
45	26	194	459	112	2	9
50	23	171	389	101	2	9
55	22	152	334	91	2	8
60	20	137	291	84	2	8
65	19	124	256	77	2	8
70	18	113	228	71	2	8
75	17	104	204	67	1	7
80	16	96	184	62	1	7
85	15	89	167	59	1	7
90	14	83	153	55	1	7
100	13	73	129	50	1	7
110	12	65	111	45	1	6
120	11	59	97	41	1	6
130	10	53	85	38	1	6
140	10	49	76	35	1	6
150	9	45	68	33	1	6
160	9	41	61	31	1	6
170	8	38	56	29	1	5

[a] See Table 1 for a description of the severity-of-ill-effect scores.

[b] From Anderson et al. 1996.

[c] From Newcombe and Jensen (1996); see Table 2 for model attributes.

[d] Juvenile + adult salmonids.

[e] Adult salmonids.

[f] Juvenile salmonids.

[g] Egg + larvae of salmonids and nonsalmonids.

[h] Adult nonsalmonids.

habitat model, moderate to moderately severe habitat degradation would be predicted if the TSS concentrations associated with the shaded durations were sustained for up to 60 days.

The Newcombe and Jensen (1996) models predict that for a duration of exposure equal to 60 days, the maximum TSS concentrations that would *not exceed* the lethal and paralethal threshold are as follows:

> 80 mg/L for juvenile salmonids
>
> 110 mg/L for juvenile and adult salmonids modeled together
>
> 160 mg/L for adult salmonids

The equivalent TSS concentration based on the Anderson et al. (1996) acute fish habitat impact model is 15 mg/L. However, it is important to note that although Anderson et al. (1996) assigned SEV scores that "followed" the Newcombe and Jensen (1996) SEV scale (Table 1), they only reported assigning an SEV equal to either 3, 7, 10, 12, or 14 (not 9). The authors suggested that the exposure levels that "approach" causing habitat damage are based on a SEV=7—defined in their report as "moderate habitat degradation—measured by a change in the invertebrate community."

When Table 3 is recomputed for the Anderson et al. (1996) model using a SEV=7, the maximum TSS concentration that would not exceed the lethal and paralethal threshold after a duration of 60 days is 5 mg/L. Under the same criteria, the TSS concentration associated with a SEV=10 is 60 mg/L. Anderson et al. (1996) defined the SEV=10 as "moderately severe habitat degradation—as defined by measurable reductions in the productivity of habitat for extended periods (months) or over a large area (kms)."

For the egg and larval life stages of salmonids and nonsalmonids, Newcombe and Jensen's (1996) model predicts the lethal and paralethal threshold to be exceeded at any TSS concentration ≥1 mg/L after 5 days of exposure. The same would be predicted for adult nonsalmonids after 41 days of exposure.

These models suggest that for a duration no longer than 60 days, an appropriate upper limit for the protection of juvenile salmonids is 80 mg/L of TSS, and up to 160 mg/L for adult salmonids. However, for the early life stages of fish and adult nonsalmonids, they suggest protection from lethal and paralethal effects cannot be afforded at TSS concentrations ≥1 mg/L when sustained for 60 days.

Thus, based on these models, a maximum target TSS limit of 80 mg/L would be required to protect juvenile salmonids; however, special consideration would have to be given to nonsalmonids, the early life stages of fish, and fish habitat—all requiring a lower TSS concentration for protection against lethal and paralethal effects.

Acute Habitat Impact Model Developed by Anderson et al. (1996)

The model developed by Anderson et al. (1996) provides a tool for selecting a TSS concentration that would be protective of fish and their habitat from acute sediment release episodes. Anderson et al. (1996) data included subsets of Newcombe and Jensen's (1996) database (as well as data compiled by Newcombe and others in previous work) and some 53 new documents of TSS effects. The new information was weighted heavily toward field data. The subset of data from Newcombe and others work only included information on events less than one month in duration, since the goal of Anderson et al. (1996) was to quantify acute effects rather than chronic effects.

Reviewing the calculated durations shown in Table 3 for the acute habitat impact model, it can be seen that 80 mg/L could be sustained for up to 2 weeks and still be protective against acute impacts. Or, in other words, the model predicts that after a 2-week period, with TSS concentrations ≥80 mg/L, acute impacts would occur.

Other Studies

Results from Buck's (1956) study of SS and selected species of warm water fish would suggest setting an upper limit for the protection of a fishery no higher than 100 mg/L. Because fish from ponds in the "intermediate" SS concentration range of 25 to 100 mg/L (based on averages) exhibited lower total weights, slower growth rates, and a reduced reproduction rate and success compared to those from ponds with an average SS concentration of <25 mg/L, a concentration below 100 mg/L might be more appropriate for protection of a fishery. Making a "finer" split of the 25 to 100 mg/L range would be purely speculative based on this study; however, the range of SS concentrations and the associated "impacts" are consistent with the SS concentration ranges set forth or measured in many of the other studies presented in this memo.

Results from Peters' (1967) study suggest that a concentration as high as 80 mg/L may be protective of a healthy fishery—including all life stages. However, it could not be determined from the study whether the young-of-year brown trout collected in the vicinity of the stream where the median monthly SS concentration was 79 mg/L migrated downstream from an area where the median monthly SS concentration was only 18 mg/L. Also, because the raw data of twice-weekly measurements were not published with the study, the exact magnitudes and durations of SS concentrations cannot be ascertained; however, based on a description of the study area, the climate, land use, and timing of hydrologic events were similar to those in the lower Boise River watershed today.

Results from Sweeten's (1998) laboratory study dealing with juvenile and larval smallmouth bass and bluegill indicate that a protective SS concentration should be much lower than 80 or 100 mg/L if the larval stage is to be protected. This study suggests that the existing TSS criteria presented from other states and the model developed by Newcombe and Jensen (1996) for the egg and larval stages of fish may not be overly protective or conservative.

Based on a personal communication (1998), Sweeten intends to be working under an EPA grant in the near future to further explore the effects of TSS on fish during the life stage immediately following yolk-sac absorption. It is during this time, when the fish transitions to becoming a sight-feeder, that he believes the fish may be most vulnerable to elevated SS concentrations. To date, however, the results from his first study have not been field verified.

Conclusions and Recommendation

The effects of suspended sediment on fish will vary with life stage, species, concentration of SS, duration of exposure, and SS particle size and shape. The early life stages of fishes clearly seem to be the most sensitive to TSS doses, whereas the larger adult fish seem to be able to withstand higher TSS concentrations and longer durations of exposure.

Suggested or existing TSS standards typically range from 25 to 80 mg/L. The higher end of this range seems to have been derived from the impacts of TSS on adult fish, whereas the low-end concentrations seems to be related to protecting the more sensitive life stages of fish—the egg and larval stages. Models developed to predict the impact of various sediment doses would support either ends of this range, depending on the life stage and species of concern, as well as the duration of exposure.

Duration of TSS exposure is a significant variable in determining the severity of ill effect on fish. Even at 25 mg/L, if sustained for a long enough period of time, this concentration may result in significant negative effects. In a laboratory environment, at least one study indicates that over a period as short as 7 days, TSS concentrations as low as 35 mg/L can result in greater than 50 percent mortality of fish larvae. In a Montana field study, however, young-of-year brown trout were collected in the vicinity of a stream sampling location that had a median monthly TSS concentration of 79 mg/L, measured twice weekly over 2 years. In either case, some uncertainty exists: To date, the laboratory study has not been field tested; and in the field study, the young-of-year trout may have migrated downstream from an area with a median monthly TSS concentration of only 18 mg/L.

Based on the durations of the seasonal hydrologic events in the lower Boise River, the various life stages and species of fish present from Lucky Peak Dam to the Snake River, and because spawning of various species occurs throughout the river, the recommended TSS concentration limit for the protection of the lower Boise River fishery and aquatic community is 50 to 80 mg/L . The 50 mg/L target is intended to be protective against the ill effects attributable to a 60-day chronic TSS exposure, whereas the 80 mg/L target is to be protective against a 14-day acute TSS exposure.

In the absence of TSS duration data, it is recommended that these targets be based on geometric means over the 60- and 14-day durations, respectively. However, it is important to realize that sustaining these recommended TSS limits beyond the 60- and 14-day durations would not afford protection of the aquatic communities. These durations are based on the fact that the river experiences periods of low TSS concentrations—periods that are essential for providing "relief" from the potential of sustained elevated TSS concentrations. If ongoing and future TSS monitoring indicates that the maximum length of time for which elevated TSS concentrations are sustained is actually less than 60 days, then the chronic TSS limit can be adjusted. For example, if this duration is determined to be only 30 days, then the appropriate TSS concentration for protection against chronic effects may only be 100 mg/L based on a 30-day geometric mean.

In light of the existing and pending research involving the effects of TSS on the sensitive, early life stages of fishes, and the importance of a long-term self-sustaining fishery, it is emphasized that the recommended limit of 50 to 80 mg/L should not be reason, or provide incentive to point- and nonpoint-sources that may currently be discharging (continuously or discontinuously) at concentrations <50 mg/L, to increase their sediment mass loading to a level that results in a *sustained* TSS concentration equal to the recommended limit.

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Appendix A

Selected Data Sets from Newcombe and Jensen's (1996) Meta-Analysis Database

inbow Trout

	Behavioral			Sublethal			Lethal and Paralethal		
	Conc. (mg/l)	Duration (days)	Scale of Severity: Description of Effect	Conc. (mg/l)	Duration (days)	Scale of Severity: Description of Effect	Conc. (mg/l)	Duration (days)	Scale of Severity: Description of Effect
Eggs/embryo							7	48	11: [E] Mortality rate 40%
							21	48	13: [E] Mortality rate 72%
							47	48	14: [E] Mortality rate 100%
							57	62	12: [E] Mortality rate 47% (controls, 32%)
							101	60	14: [E] Mortality rate 98% (controls, 15%)
							120	16	13: [E] Mortality rates 60-70% (controls, 39%)
							157	72	14: 100% mortality of eggs
							1,750	6	10: [EE] Mortality rate greater than controls (controls, 6%)
Juvenile				171	4	8: [J] Particles penetrated cells of branchial epithelium	90	19	10: [Y] Mortality rates 0-20% (DE)
				4,887	16	8: [J] Hyperplasia of gill tissue	90	19	10: [Y] Mortality rates 0-15% (KC)
				4,887	16	8: [J] Parasitic infection of gill tissue	270	19	11: [Y] Mortality rates 10-35% (KC)
							270	19	12: [Y] Mortality rates 25-80% (DE)
							810	19	12: [Y] Mortality rates 35-85% (DE)
							810	19	12: [Y] Mortality rates 5-80% (KC)
							1,750	20	12: [FF] Mortality rate 57% (control 5%)
							2,120	28	14: [Y] Mortality rate 100%
							4,250	28	12: [Y] Mortality rate 50%
							4,315	2.4	10: [Y] Mortality rates ~100% (CSS)
							7,433	28	11: [Y] Mortality rate 40% (CS)
Adult	66	0.04	3: Avoidance behavior manifested part of the time	100	0.01	5: Rate of coughing increased (FSS)	18	30	10: Abundance reduced
	100	>0.01	3: Fish avoided turbid water (avoidance behavior)	250	0.01	5: Rate of coughing increased (FSS)	50	40	9: Rate of weight gain reduced (CWS)
	665	0.04	3: Fish attracted to turbidity	810	21	8: Gills of fish that survived had thickened epithelium	50	40	9: Rate of weight gain reduced (WF)
				17,500	7	8: Fish survived; gill epithelium proliferated and thickened	59	93	10: Habitat damage; reduced porosity of gravel
							200	1	10: Test fish began to die on the first day (WF)
							270	135	10: Survival rate reduced
							810	21	10: Some fish died
							3,500	62	13: Catastrophic reduction in population size
							4,250	25	12: Mortality rate 50% (CS)
							49,838	4	12: Mortality rate 50% (DM)
							80,000	1	10: No mortality
							160,000	1	14: Mortality rate 100%

[J] juvenile
[EE] eyed egg
[FF] young fry
[DE] diatomaceous earth

[CS] calcium sulfate
[WF] wood fibers
[FSS] fine
[E] egg

[Y] approx. yearling
[KC] kaolin clay
[CWS] coal washery solids
[DM] drilling mud (non toxic)

	Behavioral			Sublethal			Lethal and Paralethal		
	Conc. (mg/l)	Duration (days)	Scale of Severity: Description of Effect	Conc. (mg/l)	Duration (days)	Scale of Severity: Description of Effect	Conc. (mg/l)	Duration (days)	Scale of Severity: Description of Effect
Brown Trout									
Eggs/embryo							110	60	14: 98% mortality of eggs
Adult				1,040	730	8: Gill lamellae thickened (VFSS)	18	30	10: Abundance reduced
				1,210	730	8: Some gill lamellea became fused (VFSS)	100	30	11: Population reduced
							1,040	365	14: Population one-seventh of expected size
							5,838	365	14: Fish numbers one-seventh of expected
Trout									
Eggs/embryo							117	40	10: [E] Mortality; deterioration of spawning gravel
Adult				16.5	1	4: Feeding behavior apparently reduced	300	30	12: Decrease in population size
				[illegible]75	[illegible]7	[illegible] 7: Reduced quality of rearing habitat	525	25	10: No mortality (other end points not investigated)
				270	13	8: Gill tissue damage			
Mountain Whitefish									
Adult							10,000	1	10: Fish died; silt-clogged gills

	Behavioral			Sublethal			Lethal and Paralethal		
	Conc. (mg/l)	Duration (days)	Scale of Severity: Description of Effect	Conc. (mg/l)	Duration (days)	Scale of Severity: Description of Effect	Conc. (mg/l)	Duration (days)	Scale of Severity: Description of Effect
Largemouth Bass (warmwater species)									
Adult									
							63	30	9: Weight gain reduced ~50%
							145	30	9: Growth retarded
							145	30	12: Fish unable to reproduce
Adult Nonsalmonids (species not specified)									
Adult									
							22	365	12: Fish populations destroyed
							120	16	10: Density of fish reduced
							620	2	10: Fish kills downstream from sediment source

Appendix B

Selected Data Sets from Newcombe and MacDonald's (1991) TSS Review

	vertebrates								
	Behavioral			Sublethal			Lethal		
	Conc. (mg/l)	Duration (days)	Effect	Conc. (mg/l)	Duration (days)	Effect	Conc. (mg/l)	Duration (days)	Effect
Benthic invert.							8	0.10	increased rate of drift
							8	60	up to 50% reduction in standing crop
							16	60	Reduction in standing crop
							32	60	Reduction in standing crop
							62	100	77% reduction in population
							77	100	53% reduction in population
							278	100	80% reduction in population size
							390	30[a]	Reduction in population size
							743	100	85% reduction in population size
							1,700	0.08	alter. comm. structure and drift patterns
							5,108	100	94% reduction in population size
							29	30[a]	Populations of Trichoptera, Ephemeroptera, Crustacea, and Mollusca, disappear
Bottom fauna							261-390	30[a]	Reduction in population size
Zoobenthos							10-15	30[a]	Reduction in standing crop
							>100	28[a]	Reduction in standing crop
Cladocera							82-392	3[a]	Survival and reproduction harmed
Cladocera and Copepoda							300-500	3	Lethal: Gills and gut clogged
Stream invert.							130[b]	365	Lethal: 40% reduction in species diversity
							25,000[b]	365	Reduction or elimination of populations
	24[a]	<0.01	Reduced capacity to assimilate food						
							53-92	1[a]	Reduction in population size

[a] Estimated

[b] China clay

Appendix C

Data Tables from Peters (1967) on the Effects of Sediment from Agricultural Practices on a Montana Trout Stream

Table C-1

Monthly Average Suspended-Sediment Concentration in Parts per Million Based on Approximately Twice Weekly Samples from April 1960 to March 1962 at Five Stations on Bluewater Creek

Month	1960-61 Station					1961-62 Station				
	I	II	III	IV	V	I	II	III	IV	V
April	37	118	192	123	323	16	113	178	118	185
May	27	122	147	139	310	35	86	241	280	2280
June	33	92	119	85	395	17	58	120	197	319
July	16	72	104	115	188	11	42	201	210	428
August	12	49	188	229	577	13	35	204	199	355
September	16	20	85	73	242	39	79	357	754	2030
October	19	39	104	211	314	23	75	189	284	353
November	14	36	64	188	252	20	97	174	328	254
December	10	45	126	179	221	13	118	142	282	246
January	22	69	194	291	267	16	147	276	343	398
February	14	55	167	137	159	28	160	378	574	556
March	16	96	119	105	114	25	131	156	323	368

From: Peters, J.C. 1967. Effects on a Trout Stream of Sediment from Agricultural Practices. *Journal of Wildlife Management* 31(4):805-812.

Table C-2
Monthly Mean Maximum and Minimum Temperature (C) at
Two Stations in Bluewater Creek from January 1961 Through December 1961

Month	Station II Mean Monthly		Station IV Mean Monthly	
	Max.	Min.	Max.	Min.
January	9.4	4.4	6.7	2.8
February	10.6	4.4	7.8	3.3
March	12.2	4.4	10.0	3.9
April	13.9	5.6	12.8	5.6
May	17.2	7.2	17.8	8.9
June*	18.3	6.7	22.8	15.6
July	19.4	8.3	23.9	17.2
August	18.3	6.7	21.7	15.6
September	13.3	6.1	13.3	9.4
October	11.7	5.6	11.1	5.6
November	10.0	4.4	7.8	4.4
December	10.0	6.7	5.6	2.8

*Values for Station II based on 27 days in June.

From: Peters, J.C. 1967. Effects on a Trout Stream of Sediment from Agricultural Practices
Journal of Wildlife Management 31(4):805-812.

Table C-3

Number of Trout and Rough Fish Captured by Electrofishing in 4,000-Square-Foot Areas During August and September 1961 in Bluewater Creek

	Station									
	I		II		III		IV		V	
Section	Trout	Rough Fish	Trout	Rough Fish	Trout	Rough Fish	Trout	Rough Fish	Trout	Rough Fish
1	177	9	209	0	87	238	10	1446	4	425
2	230	6	218	19	36	141	7	1515	9*	471*
3	241	4	164	30	40	296	7	641	4*	236*
Average	216	7	197	17	55	225	8	1201	6	378

*Sampled in May 1962.

From: Peters, J.C. 1967. Effects on a Trout Stream of Sediment from Agricultural Practices. *Journal of Wildlife Management* 31(4):805-812.

Table C-4

Population Estimate of Trout by Mark and Recapture in Bluewater Creek (One section sampled near each station)

Station No.	Number of Trout Captured by Electrofishing	Estimate Total Number of Trout Without Separation by Size Classes		Estimate Total Number of Trout With Separation by Size Classes	
I	230	266	(86)*	269	(86)*
II	164	197	(83)*	198	(83)*
III	87	102	(85)*	102	(85)*
IV	7	8	(88)*	8	(88)*
V	4	6	(67)*	6	(67)*

*Ratio of the number of trout captured by electrofishing to the estimate of the total number of trout.

From: Peters, J.C. 1967. Effects on a Trout Stream of Sediment from Agricultural Practices. *Journal of Wildlife Management* 31(4):805-812.

Table C-5

Mortality of Eyed Rainbow Eggs Incubated in Five Areas of Bluewater Creek

Station	Percent Mortality			Average Mortality (Percent)
	Box 1	Box 2	Box 3	
I	2	4	4	3
II	35	22	8	22
III	81	38	42	54
IV	51	83	75	70
V	19	37	83	47

Notes:

1. An estimated 476 eggs were placed in the streambed in each Vibert box on May 24, 1961; pulled out on June 2, 1961.
2. The relatively low mortality of eggs at Station V was attributed to high flows that carried out the sediment rather than depositing it in the streambed gravels.

From: Peters, J.C. 1967. Effects on a Trout Stream of Sediment from Agricultural Practices. *Journal of Wildlife Management* 31(4):805-812.

Appendix B

USGS Lower Boise River Sediment Water Quality Data

DISTRICT CODE 16

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS DATE 10/16/97

Station Number 13203510

WATER - QUALITY DATA

Date	Discharge Inst. Cubic Ft/Sec (00061)	Turbidity (NTU) (00076)	Sediment, Suspended (MG/L) (80154)	Sediment, Discharge, Suspended (T/Day) (80155)
11/20/90	175	2.1	8	3.8
3/28/91	177	2	3	1.4
5/22/91	1350	11	3	11
9/11/91	737	1	4	8
5/4/93	2700		4	29
5/18/93	5680		3	46
6/3/93	2510		4	27
9/1/93	1690		3	14
11/3/93	258	0.7	3	2.1
3/10/94	245	1.0	41	27
5/11/94	1770	0.4	2	9.6
9/13/94	620	1.0	8	13
11/14/94	161		6	2.6
4/13/95	1420		28	107
4/26/95	4640		6	75
5/16/95	4610		2	25
6/12/95	2620		2	14
8/14/95	1830		1	4.9
9/19/95	337		27	25
12/7/95	200		5	2.7
2/13/96	4000		4	43
4/11/96	5900		5	80
4/22/96	5400		7	102
5/15/96	4650		4	50
6/12/96	7800		5	105
8/21/96	2100		3	17
10/21/96	321		6	5.2
12/16/96	240		2	1.3
2/10/97	7010		38	720
4/14/97	7700		9	187
6/9/97	4570		6	74
7/14/97	2300		3	19
8/11/97	2160		3	17
Min	161	0.4	1	1.3
Max	7800	11	41	720
Average	2663	2	8	57
Count	33	8	33	33

GLENWOOD BRIDGE
DISTRICT CODE 16
UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS DATE 10/16/97
Station Number 13206000
WATER - QUALITY DATA

Date	Discharge Inst. Cubic Ft/Sec (00061)	Turbidity (NTU) (00076)	Sediment, Suspended (MG/L) (80154)	Sediment, Discharge, Suspended (T/Day) (80155)
11/22/89	185	1.5	4	1.9
3/16/90	147	3.5	7	2.8
5/29/90	850	7.8	20	46
7/9/90	736		8	16
9/21/90	491	1.6	5	6.6
11/19/90	169	1.6	3	1.4
3/28/91	157	2.4	7	3
5/22/91	602	1.9	11	18
9/11/91	574	1.1	6	9.3
11/12/91	153	1.6	5	2.1
3/18/92	114	3.2	7	2.2
5/14/92	732	2	8	16
9/11/92	287	3	7	5.4
11/2/92	83	1.2	4	0.90
1/7/93	71			
3/10/93	120	3.3	6	1.9
5/4/93	2270		120	735
5/12/93	2,570	6.2	14	97
5/18/93	4970		36	483
6/2/93	1690		32	146
8/6/93	1130	9.7		
9/1/93	748		4	8.1
9/14/93	626	1.2	83	140
11/1/93	240	0.6	2	1.3
5/4/94	248	0.6	30	20
5/13/94	806	0.4	4	8.7
9/9/94	398	0.9	6	6.4
11/10/94	188	1.2	3	1.5
3/20/95	167	4.6	12	5.4
4/13/95	923		23	57
4/26/95	3,450		52	484
5/16/95	3,990	2.0	24	259
6/12/95	1,710		5	23
8/14/95	790		4	8.5
9/19/95	811	13.0	16	35
10/19/95	321		5	4.3
12/7/95	235		4	2.5
2/13/96	3,760		67	680
4/11/96	5,690	2.9	22	338
4/22/96	4,910		17	225
5/16/96	3,790	2.0	25	256
6/11/96	5,060	2.0	20	273

DISTRICT CODE 16
UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS DATE 10/16/97
Station Number 13206000
WATER - QUALITY DATA

Date	Discharge Inst. Cubic Ft/Sec (00061)	Turbidity (NTU) (00076)	Sediment, Suspended (MG/L) (80154)	Sediment, Discharge, Suspended (T/Day) (80155)
7/12/96	1,340	0.6	12	43
8/21/96	1,250	1.1	4	13
9/24/96	743	1.5	4	8.0
10/21/96	386		3	3.1
12/16/96	446		3	3.6
2/10/97	6,860		53	982
4/15/97	6,850	5.2	20	370
5/23/97	4,630		27	338
6/9/97	4,100	4.2	10	111
7/16/97	1,400	5.2		
8/11/97	1,420	1.4	4	15
9/8/97	1,420	1.9		
Min	71	0	2	1
Max	6,860	13	120	982
Average	1,626	3	18	126
Count	54	36	50	50

DISTRICT CODE 16
UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS DATE 10/16/97
Station Number 13210050
WATER - QUALITY DATA

Date	Discharge Inst. Cubic Ft/Sec (00061)	Turbidity (NTU) (00076)	Sediment, Suspended (MG/L) (80154)	Sediment, Discharge, Suspended (T/Day) (80155)
11/13/91	241	1.7	11	7.2
3/18/92	174	3.9	11	5.2
5/11/92	169	3	15	6.8
9/11/92	161	1.6	8	3.5
5/5/93	1910		71	88
5/19/93	4460		30	361
6/3/93	625		29	49
9/1/93	245		6	4
5/12/94	234		10	6.3
11/9/94	258	1.2	5	3.5
3/10/95	224	1.4	15	9.1
4/13/95	765		30	62
4/28/95	3,630		211	2070
5/17/95	3,760	2.7	18	183
6/13/95	1,160		7	22
8/15/95	573		5	7.7
9/11/95	417	1.0	6	6.8
10/19/95	356		4	3.8
12/5/95	382		4	4.1
2/14/96	4,000		28	302
4/11/96	4,800		17	220
4/23/96	4,200		2	23
5/15/96	3,240		15	131
6/13/96	4,690		24	304
8/22/96	620		6	10
10/24/96	412		4	4.4
12/16/96	342		4	3.7
4/16/97	5,640		14	213
7/15/97	704		17	32
8/11/97	783		8	17
Min	161	1	2	4
Max	5,640	4	211	2,070
Average	1,639	2	21	139
Count	30	8	30	30

PARMA
DISTRICT CODE 16
UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS DATE 10/16/97
Station Number 13213000
WATER - QUALITY DATA

Date	Discharge Inst. Cubic Ft/Sec (00061)	Turbidity (NTU) (00076)	Sediment, Suspended (MG/L) (80154)	Sediment, Discharge, Suspended (T/Day) (80155)
1/23/74	1040		71	199
3/20/74	5260		57	814
6/25/74	6300		154	2620
7/23/74	758		76	156
9/4/74	810		47	103
10/16/74	1140		28	86
11/18/74	1090		18	53
12/12/74	1020		664	1830
1/21/75	920		20	50
2/24/75	944		39	99
3/21/75	2070		56	313
4/23/75	7500		46	931
5/28/75	5950		52	835
6/24/75	1310		84	297
7/17/75	1120		102	308
8/25/75	1280		483	1670
9/17/75	933		40	101
[illegible]/17/75	1300		147	516
11/18/75	1050		9	26
12/22/75	1030		22	61
1/21/76	2770		467	3490
2/19/76	1080		26	76
3/17/76	3140		66	560
4/21/76	5740		111	1720
5/20/76	3680		145	1440
6/30/76	624		84	142
7/21/76	902		112	273
8/17/76	1360		74	272
9/22/76	13900		43	1610
10/14/76	1110		20	60
11/16/76	1090		18	53
12/15/76	965		17	44
1/12/77	784		32	68
2/9/77	669		28	51
3/8/77	650		32	56
4/12/77	344		23	21
5/10/77	523		102	144
6/7/77	219		23	14
7/21/77	275		72	53
[illegible]/10/77	273		33	24
9/8/77	364		19	19
10/12/77	575		8	12

DISTRICT CODE 16
UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS DATE 10/16/97
Station Number 13213000
WATER - QUALITY DATA

Date	Discharge Inst. Cubic Ft/Sec (00061)	Turbidity (NTU) (00076)	Sediment, Suspended (MG/L) (80154)	Sediment, Discharge, Suspended (T/Day) (80155)
6/10/81	6120		129	2130
11/12/86	2230	4.8	35	211
1/22/87	827	4.9	53	118
3/19/87	933	9	54	136
5/28/87	1270	32	145	497
7/27/87	549	25	61	90
9/9/87	732	4.3	42	83
11/23/87	906	1.8	54	132
1/13/88	761	2.9	60	123
3/14/88	667	4.2	31	56
5/23/88	380	14	52	53
7/20/88	258	1.6	45	31
9/21/88	514	6.5	25	35
11/10/88	842	4.9	16	36
1/19/89	723	6.2	30	59
3/13/89	1130	29	101	308
5/8/89	1400	17	71	268
7/5/89	543	37	95	139
8/29/89	1100	17	66	196
11/16/89	950	3.5	12	31
1/30/90	1420	10	30	115
3/26/90	323	4	22	19
5/21/90	830	30	148	332
7/12/90	309	19	48	40
9/17/90	784	9.6	39	83
11/21/90	888	4	15	36
1/16/91	932	15	46	116
3/25/91	587	6	48	76
5/20/91	1400	28	120	454
7/22/91	608	30	91	149
9/10/91	796	23	107	230
11/14/91	808	3	61	133
1/22/92	660	5.4	26	46
3/17/92	564	6.5	27	41
5/12/92	308	17	57	47
9/8/92	170		41	19
11/3/92	648	4.5	18	31
1/5/93	576	3.5	15	23
3/11/93	723	8.0	33	64
5/13/93	2,170	15.0	63	369
9/8/93	772	4.4	40	83
11/2/93	981	0.8	12	32

DISTRICT CODE 16
UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY   PROCESS DATE 10/16/97
Station Number 13213000
WATER - QUALITY DATA

Date	Discharge Inst. Cubic Ft/Sec (00061)	Turbidity (NTU) (00076)	Sediment, Suspended (MG/L) (80154)	Sediment, Discharge, Suspended (T/Day) (80155)
1/19/94	870	3.7		
3/1/94	800	2.8	83	179
5/10/94	587	34.0	89	141
9/7/94	444	2.2	20	24
11/8/94	779	3.2	15	32
2/15/95	686	4.5	34	63
4/14/95	1,270		164	562
4/27/95	3,560		163	1570
5/18/95	4,380	5.1	37	438
6/14/95	1,010		59	161
7/19/95	1,420	12.0	245	939
8/16/95	1,080		51	149
10/18/95	942		15	38
12/5/95	935		18	45
2/15/96	5,360		70	1010
4/10/96	6,320		58	990
4/24/96	5,040		43	585
[illegible]/17/96	5,320		89	1280
6/10/96	5,100		46	633
8/21/96	1,140		34	105
10/23/96	1,190		18	58
12/17/96	929		14	35
2/11/97	8,580		47	1090
4/17/97	6,340		26	445
5/22/97	4,760		47	604
6/10/97	4,280	10.0	47	543
7/18/97	1,350	20.0		
8/12/97	1,500	6.2	32	130
9/9/97	1,510	3.7		
Min	170	1	8	12
Max	13,900	37	664	3,490
Average	1,783	11	69	367
Count	113	52	110	110

DISTRICT CODE 16
UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS DATE 10/16/97
Station Number 13206400
WATER - QUALITY DATA

Date	Discharge Inst. Cubic Feet Per Second (00061)	Sediment, Suspended (MG/L) (80154)	Sediment, Discharge, Suspended (T/Day) (80155)
5/3/94	39	74	7.8
11/15/94	13	12	0.42
5/17/95	29	7	0.55
12/5/95	11	64	1.9
5/14/96	29	90	7.1
6/9/97	33	11	0.98
Min	11	7	0.42
Max	39	90	7.8
Average	26	43	3.1
Count	6	6	6

DISTRICT CODE 16
UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS DATE 10/16/97
Station Number 13209450
WATER - QUALITY DATA

Date	Discharge Inst. Cubic Feet Per Second (00061)	Sediment, Suspended (MG/L) (80154)	Sediment, Discharge, Suspended (T/Day) (80155)
5/3/94	29	20	1.6
11/15/94	10	11	0.30
5/18/95	14	12	0.46
12/7/95	14	11	0.42
5/14/96	14	11	0.42
6/9/97	16	3	0.13
Min	10	3	0.13
Max	29	20	1.6
Average	16	11	0.56
Count	6	6	6

DISTRICT CODE 16

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY   PROCESS DATE 10/16/97

Station Number 13210810

WATER - QUALITY DATA

Date	Discharge Inst. Cubic Feet Per Second (00061)	Sediment, Suspended (MG/L) (80154)	Sediment, Discharge, Suspended (T/Day) (80155)
5/4/94	116	192	60
11/16/94	23	9	0.57
4/11/95	83	196	44
4/24/95	110	152	45
5/17/95	119	67	22
6/15/95	89	133	32
8/17/95	99	100	27
10/17/95	62	8	1.3
12/5/95	36	13	1.3
2/14/96	37	23	2.3
4/11/96	118	518	165
4/23/96	170	111	51
5/16/96	199	167	90
6/13/96	104	65	18
8/20/96	147	56	22
10/21/96	60	5	0.81
12/19/96	33	20	1.8
2/13/97	51	20	2.7
6/12/97	182	95	47
7/16/97	167	139	63
8/13/97	156	65	27
Min	23	5	0.57
Max	199	518	165
Average	103	103	34
Count	21	21	21

DISTRICT CODE 16
UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS DATE 10/16/97
Station Number 132108247
WATER - QUALITY DATA

Date	Discharge Inst. Cubic Feet Per Second (00061)	Sediment, Suspended (MG/L) (80154)	Sediment, Discharge, Suspended (T/Day) (80155)
5/3/94	139	48	18
11/15/94	66	23	4.1
5/12/95	157	62	26
12/5/95	65	29	5.1
5/13/96	116	51	16
6/10/96	149	19	7.6
7/15/96	166	17	7.6
8/12/96	146	11	4.3
Min	65	11	4.1
Max	166	62	26
Average	126	33	11
Count	8	8	8

DISTRICT CODE 16

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS DATE 10/16/97

Station Number 13210835

WATER - QUALITY DATA

Date	Discharge Inst. Cubic Feet Per Second (00061)	Sediment, Suspended (MG/L) (80154)	Sediment, Discharge, Suspended (T/Day) (80155)
5/2/94	75	102	21
11/17/94	1.5	3	0.01
4/18/95	82	124	27
4/26/95	56	71	11
5/12/95	118	162	52
6/7/95	46	42	5.2
8/14/95	18	50	2.5
10/16/95	33	13	1.2
12/4/95	1.7	11	0.05
2/12/96	41	190	21
4/8/96	20	36	2
4/25/96	121	357	117
5/13/96	27	25	1.8
6/11/96	42	68	7.7
8/19/96	28	68	5.2
10/22/96	32	10	0.87
12/18/96	939	5	13
2/12/97	299	196	158
6/10/97	59	38	6
Min	1.5	3	0.01
Max	939	357	158
Average	107	83	24
Count	19	19	19

MASON SLOUGH AT MOUTH NR CALDWELL
DISTRICT CODE 16
UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS DATE 10/16/97
Station Number 13210850
WATER - QUALITY DATA

Date	Discharge Inst. Cubic Feet Per Second (00061)	Sediment, Suspended (MG/L) (80154)	Sediment, Discharge, Suspended (T/Day) (80155)
5/4/94	21	112	6.4
11/16/94	12	202	6.7
5/15/95	15	55	2.2
12/7/95	9.0	128	3.1
5/14/96	42	73	8.3
5/18/97	17	23	1.1
Min	9.0	23	1.1
Max	42	202	8.3
Average	19	99	4.6
Count	6	6	6

DISTRICT CODE 16

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS DATE 10/16/97

Station Number 13210985

WATER - QUALITY DATA

Date	Discharge Inst. Cubic Feet Per Second (00061)	Sediment, Suspended (MG/L) (80154)	Sediment, Discharge, Suspended (T/Day) (80155)
5/4/94	126	335	114
11/16/94	47	17	2.1
4/12/95	28	21	1.6
4/24/95	75	122	25
5/15/95	116	116	36
6/15/95	134	191	69
8/17/95	168	116	53
10/17/95	84	28	6.4
12/7/95	61	81	13
2/16/96	62	131	22
4/9/96	59	84	13
4/26/96	92	263	65
5/14/96	121	525	172
6/12/96	124	407	136
10/24/96	93	12	3.0
12/18/96	58	47	7.4
2/12/97	77	73	15
6/11/97	170	159	73
7/16/97	155	135	56
8/13/97	142	55	21
Min	28	12	1.6
Max	170	525	172
Average	100	146	45
Count	20	20	20

DISTRICT CODE 16

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS DATE 10/16/97

Station Number 13210987

WATER - QUALITY DATA

Date	Discharge Inst. Cubic Feet Per Second (00061)	Sediment, Suspended (MG/L) (80154)	Sediment, Discharge, Suspended (T/Day) (80155)
5/5/94	64	157	27
11/18/94	23	55	3.4
4/11/95	16	14	0.61
4/25/95	25	56	3.8
5/11/95	50	60	8.1
6/7/95	66	91	16
8/15/95	96	75	19
10/16/95	63	41	6.9
12/4/95	25	46	3.1
2/12/96	21	21	1.2
4/8/96	17	14	0.64
4/25/96	34	91	8.4
5/13/96	63	133	23
6/11/96	71	70	13
8/19/96	85		
10/22/96	40	35	3.7
2/18/96	22	52	3.0
2/12/97	13	15	0.51
6/10/97	72	87	17
Min	13	14	0.51
Max	96	157	27
Average	46	62	8.8
Count	19	18	18

DISTRICT CODE 16
UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS DATE 10/16/97
Station Number 13210986
WATER - QUALITY DATA

Date	Discharge Inst. Cubic Feet Per Second (00061)	Sediment, Suspended (MG/L) (80154)	Sediment, Discharge, Suspended (T/Day) (80155)
5/5/94	30	84	6.7
11/17/94	8.1	3	0.07
4/11/95	5.1	8	0.11
4/25/95	11	17	0.49
5/11/95	23	49	3.0
6/7/95	40	248	27
8/15/95	44	66	7.8
10/16/95	14	10	0.38
12/4/95	7.0	15	0.28
2/12/96	7.5	11	0.22
4/8/96	5.1	16	0.22
4/25/96	22	67	4.1
5/13/96	28	93	7.0
6/11/96	31	77	6.5
8/19/96	44	114	14
10/22/96	15	6	0.25
12/18/96	7.5	18	0.36
2/12/97	7.6	33	0.67
6/10/97	36	68	6.5
Min	5.1	3	0.07
Max	44	248	27
Average	20	53	4.5
Count	19	19	19

DISTRICT CODE 16
UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS DATE 10/16/97
Station Number 13211445
WATER - QUALITY DATA

Date	Discharge Inst. Cubic Feet Per Second (00061)	Sediment, Suspended (MG/L) (80154)	Sediment, Discharge, Suspended (T/Day) (80155)
5/5/94	75	101	20
11/17/94	162	17	7.4
4/12/95	92	101	25
4/24/95	100	45	12
5/16/95	167	41	18
6/12/95	83	42	9.4
8/17/95	33	75	6.6
10/17/95	150	36	15
12/6/95	201	47	26
2/13/96	205	58	32
4/9/96	102	36	9.9
4/26/96	101	57	16
5/16/96	151	176	72
6/11/96	55	42	6.2
8/20/96	76	26	5.3
10/22/96	256	30	21
2/17/96	204	33	18
2/11/97	214	150	87
6/11/97	63	34	5.7
7/16/97	50	47	6.3
8/13/97	63	28	4.8
Min	33	17	4.8
Max	256	176	87
Average	124	58	20
Count	21	21	21

DISTRICT CODE 16

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS DATE 10/16/97

Station Number 13212550

WATER - QUALITY DATA

Date	Discharge Inst. Cubic Feet Per Second (00061)	Sediment, Suspended (MG/L) (80154)	Sediment, Discharge, Suspended (T/Day) (80155)
5/6/94	40	295	31
11/18/94	23	31	1.9
4/12/95	17	39	1.7
4/25/95	31	140	12
5/18/95	42	219	25
6/14/95	45	248	30
8/16/95	47	144	18
10/18/95	27	23	1.7
12/6/95	19	22	1.1
2/15/96	15	9	0.36
4/9/96	14	49	1.9
4/24/96	40	174	19
5/16/96	52	217	30
6/10/96	52	425	60
8/20/96	50	68	9.2
10/23/96	33	111	9.8
12/17/96	20	58	3.2
2/10/97	19	48	2.5
6/18/97	55	160	24
7/15/97	58	321	50
8/12/97	52	104	15
Min	14	9	0.36
Max	58	425	60
Average	36	138	17
Count	21	21	21

DIXIE DRAIN NR WILDER
DISTRICT CODE 16
UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS DATE 10/16/97
Station Number 13212890
WATER - QUALITY DATA

Date	Discharge Inst. Cubic Feet Per Second (00061)	Sediment, Suspended (MG/L) (80154)	Sediment, Discharge, Suspended (T/Day) (80155)
5/6/94	219	111	66
11/18/94	81	50	11
4/18/95	162	140	61
4/27/95	183	102	50
5/19/95	182	60	29
6/14/95	156	126	53
8/16/95	222	39	23
10/18/95	196	20	11
12/6/95	81	30	6.6
2/15/96	85	41	9.4
4/10/96	166	134	60
4/24/96	240	223	145
5/17/96	370	460	460
6/10/96	219	88	52
8/21/96	154	21	8.7
10/23/96	166	25	11
12/17/96	76	22	4.5
2/11/97	92	79	20
6/18/97	228	91	56
7/16/97	258	97	68
8/12/97	249	48	32
Min	76	20	4.5
Max	370	460	460
Average	180	96	59
Count	21	21	21